ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 7, July 2013

Impact of Imperfect Channel Estimation on Regenerative Cooperative Networks using Coherent and Non-coherent Detection

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Abstract: In this paper, we investigate the effect of imperfect channel estimation on decode-and-forward (DF) cooperative diversity networks. There are two phases, the broadcasting phase and the relaying phase. In the first phase, the source broadcasts the message to the relays via flat Rayleigh fading channels. Relays that are capable of correctly decoding the source message will be working in the later phase i.e. the relaying phase. Initially, the output signal-to-interference-plus-noise ratio (SINR) at the destination is derived. Error and outage probabilities are considered as the performance metrics and exact closed-form expressions are derived for the same. The closed-form expression for outage probability is obtained for both non-coherent and coherent detection methods. These results are used to study the impact of imperfect channel estimation on the regenerative cooperative network. Asymptotic expression for the average symbol error probability is also derived and the inferences are discussed.

Index terms: Outage probability, Error probability, decode-and-forward, Cooperative networks, Relaying, Co-channel Interference.

I. Introduction

An important area of communication research these days mainly focuses on the decode-and-forward (DF) cooperative systems operating in fading environments and its performance analysis. There have been many researches that addressed the problem of co-channel interference and imperfect channel estimation and their effect on decode-and-forward (DF) cooperative relaying networks or systems for e.g. [1] has addressed the problem Co-Channel Interference (CCI) and also the importance of considering of it at the destination receiver and [2] has investigated the impact of imperfect channel estimation on decode-and-forward (DF) relaying networks. Though Co-channel interference and imperfect channel estimation are very common for cooperative networks in real operating environments and their effect on them is important to understand and to be considered for a practical deployment of these networks. Furthermore, several studies as mentioned above have addressed the problem of imperfect channel estimation and interference in cooperative networks independently. Research paper [3] has showed the impact of imperfect channel estimation and co-channel interference both independently and jointly with the help of expressions for exact and approximate error probability. In this work we have obtained the closed form expressions for outage probability in both coherent and non-coherent detection cases, and using these expressions we have observed the impact of imperfect channel estimation and co-channel interference in both cases. In this situation, taking into account a multi-relay system and implementing DF(Decode-and-Forward) relaying, the main segments of this work can be divided into *i*) deriving an exact closed-form expression for the probability density function (PDF) of the output SINR(Signal-to-Interference plus Noise Ratio) at the destination node *ii*) exact error and outage probabilities are obtained in closed-form, also closed-form expressions for outage probability is derived for both non-coherent detection case and the coherent detection case.*iii*) to clearly observe the impact of co-channel interference and imperfect estimation on performance, a proximate expression for the error probability is obtained.

II. System Model

A multi-relay system implementing DF relaying is considered. As shown in Fig. 2.1, a source node (*S*) and a destination node (*D*) communicate over a frequency-flat Rayleigh fading channel represented with complex coefficient.

ISSN (Print) : 2319-5940
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International Journal of Advanced Research in Computer and Communication Engineering
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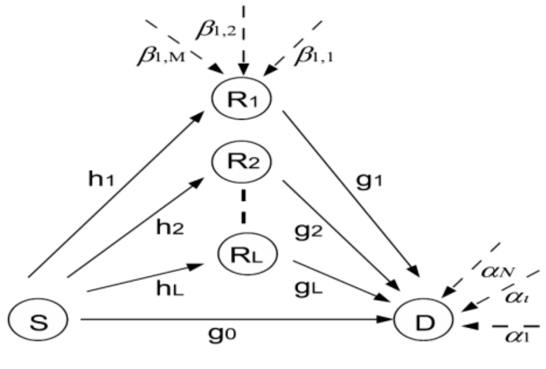

Fig 1. Multi-branch decode-and-forward cooperative diversity network with co-channel interferences.

A number of cooperating nodes (R_i , i= 1, 2, · · · , L) are also available to relay the source's signal to the final destination. In the first phase or segment, i.e., the broadcasting phase, the source broadcasts its signal to the relays and the destination node. We assume a genie-aided receiver at each relay. This genie-aided receiver is capable to determine which symbols in the transmitted data are wrongly detected at the relay. Only those relays that correctly detect the symbol at each symbol position are allowed to forward that symbol in the second phase. A decoding set C, i.e. the set of forwarding relays and this changes from symbol to symbol is considered. This is different from a DF system involving an error detection code, where the decoding set is fixed and comprises only those relays that correctly decode the entire data frame. Nonetheless, this assumption of the relays knowledge of wrong symbol after detection facilitates the error probability derivations. Moreover, it should be emphasized that the derived results under such assumption can be viewed as a bench mark to a practical system with error-detection code.

Based on the direct transmission from node S to node D during the first transmission phase, the signal received at the destination is modelled as

$$y_{S,D} = \sqrt{E_S}\, g_0 d_0 + \sqrt{E_I}\sum_{j=1}^{N}\alpha_j d_j + n_{S,D} \quad (1)$$

Where d_0 and d_j are independent transmitted symbols of desired and j^{th} interfering users, respectively. We assume that the transmitted symbols are equi-probable with unit energy. g_0 and α_j correspond to the flat Rayleigh fading channel coefficients for the desired user and j^{th} interferer. i.e.

$$g_0 \sim CN\left(0,\Omega_g\right), \alpha_j \sim CN\left(0,\Omega_\alpha\right)$$

and it is assumed that g_0 and α_j are mutually independent. Further, E_S and E_I correspond to the received signal energies of the desired user and the j^{th} interfering user, respectively. Finally, $\eta_{S,D}$ is the AWGN term at the destination node, where

$$n_{S,D} \sim CN\left(0,N_0\right),$$

During the same phase, i.e., the broadcasting phase, the received signals at the relays are given by

$$y_{S,R_i} = \sqrt{E_S}\, h_i d_0 + \sqrt{E_{I_R}}\sum_{j=1}^{M}\beta_{i,j} d_{R_{i,j}} + n_{S,D}, i = 1,2,.......,L \quad (2)$$

Where d_0 is the transmitted symbol of the desired user, $d_{R_{i,j}}$ is the j^{th} interfering symbol at the i^{th} relay, E_{I_R} represents the average received energy of the j^{th} interferer at the i^{th} relay, h_i and $\beta_{i,j}$ correspond to the flat Rayleigh fading channels from the desired user and the j^{th} interferer to the i^{th} relay i.e.,

$$h_i \sim CN\left(0,\Omega_h\right) \ , \ \beta_{i,j} \sim CN\left(0,\Omega_\beta\right)$$

also, η_{S,R_i} is the AWGN term at the i^{th} relay, where

$$n_{S,R_i} \sim CN\left(0,N_0\right)$$

Assuming that the total received interference power at the destination changes slowly and remains constant during the second transmission phase, we can express the received signal at the destination, from the i^{th} relay, as

$$y_{R_i,D} = \sqrt{E_S}\, g_i d_0 + \sqrt{E_I}\sum_{j=1}^{N}\alpha_j d_j + n_{R_i,D}, i = 1,2,.......,|C| \quad (3)$$

Where $|C|$ denotes the number of relays in the decoding set and g_i is the complex gain of the $R_i \rightarrow D$ channel distributed according to $\sim CN$ (0, Ωg) and $\eta_{R_i,D}$ is the AWGN term

$$n_{R_i,D} \sim CN\left(0,N_0\right)$$

To detect the transmitted bits, the channel h_i must be estimated at the i^{th} relay. The channel estimation error is defined as

$$e_{h_i} = h_i - \hat{h}_i$$

Where is the channel estimate. The channel estimation error, e_{h_i} is assumed to be Gaussian with variance $\sigma_{e_h}^2$. The estimation error e_{h_i} and channel estimate $\hat{h}_i$ are assumed to be mutually independent, which is valid for Minimum Mean Square Error (MMSE) estimation in which the estimate and the error are orthogonal. Therefore, the channel estimate $\hat{h}_i$ is also Gaussian distributed with variance

$\Omega_{\hat{h}} = \Omega_h - \sigma_{e_h}{}^2$ i.e. $\sim CN\left(0,\Omega_{\hat{h}}\right)$.Throughout the work, the above approach also applies to the $R_i \rightarrow D$ link, i.e.

$$\hat{g}_i \sim CN\left(0,\Omega_{\hat{g}} = \Omega_g - \sigma_{e_g}{}^2\right), i = 0,1,......,L \ .$$

ISSN (Print) : 2319-5940
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III. PERFORMANCE ANALYSIS

A. *Probability Density Function of the Output SINR*

The received signals at the destination are combined using maximum ratio combining (MRC) technique. Thus, the combined signal at the destination node D is given by

$$Z = \sum_{i=0}^{|c|} \hat{g}_i^* \left(\sqrt{E_S} g_i d_0 + \sqrt{E_I} \sum_{k=1}^{N} \alpha_j d_j + n_{R_i,D} \right) \quad (4)$$

Now the corresponding output SINR of the combined signal given C, denoted by $\gamma_{out|C}$, is given by [4]

$$\gamma_{out|c} = \frac{\sum_{i=0}^{c} P_s |\hat{g}_i|^2 \Big/ \left(P_s \sigma_{e_g}^2 + 1\right)}{1 + P_I \sum_{j=1}^{N} \left|\alpha_j^2\right| \Big/ \left(P_s \sigma_{e_g}^2 + 1\right)} = \frac{Y}{1+X} \quad (5)$$

where $P_S = E_S / N_0$ and $P_I = E_I / N_0$ .Now writing PDF of Y, considering Y to be gamma distributed

$$f_Y(y) = \left(\frac{1}{\lambda}\right)^{|C|+1} \frac{1}{\Gamma(|C|+1)} y^{|c|} \exp\left(-\frac{y}{\lambda}\right) \quad (6)$$

where $\lambda = \frac{P_S \Omega_{\hat{g}}}{P_S \sigma_{e_g}{}^2 + 1}$

Now similarly PDF of X is given by,

$$f_X(x) = \left(\frac{1}{\chi}\right)^N \frac{1}{\Gamma(N)} x^{N-1} \exp\left(-\frac{x}{\chi}\right) \quad (7)$$

Where $\chi = \frac{P_I \Omega_\alpha}{P_S \sigma_{e_g}{}^2 + 1}$ .Then, by using the approach in [3], the distribution of the SINR $\gamma_{out|C}$ can be expressed as

$$f_{\gamma_{out}}(\gamma \mid c) = \left(\frac{1}{\lambda}\right)^{|C|+1} \frac{1}{\Gamma(|C|+1)} \left(\frac{1}{\chi}\right)^N \exp\left(-\frac{\gamma}{\lambda}\right) \gamma^{|c|} \sum_{k=0}^{|c|+1} \binom{|c|+1}{k} (N)_k \frac{1}{\left(\frac{1}{\chi} + \frac{\gamma}{\lambda}\right)^{N+k}} \quad (8)$$

Using the total probability theorem unconditional PDF of the output SINR, denoted by γ_{out} , can be written as

$$f_{\gamma_{out}}(\gamma) = \sum_{t=0}^{L} f_{\gamma_{out}}(\gamma|\mathrm{t}) P_r(|\mathrm{C}|=\mathrm{t}) \quad (9)$$

Therefore,

$$f_{\gamma_{out}}(\gamma) = \sum_{t=0}^{L} \left(P_{off}\right)^{L-t} \left(1 - P_{off}\right)^t \left(\frac{1}{\lambda}\right)^{t+1} \frac{1}{\Gamma(t+1)} \left(\frac{1}{P\chi}\right)^N \exp\left(-\frac{\gamma}{\lambda}\right) \gamma^t \sum_{k=0}^{t+1} \binom{t+1}{k} \frac{(N)_k}{\left(\frac{1}{\chi} + \frac{\gamma}{\lambda}\right)^{N+k}} \quad (10)$$

Where P_{off} represents the probability that the i^{th} relay is off, i.e., inactive during the relaying phase, and $(1 - P_{off})$ represents the probability that the i^{th} relay is on, i.e., active. The second line follows by knowing that $|C|$ ranges from 0 to L. Note that for t = 0, $f_{\gamma_{out}}(\gamma)$ represents the PDF in the non-cooperative case (i.e., only direct link transmission) with probability of occurrence $\left(p_{off}\right)^L$ .Now the output of the demodulation process at the i^{th} relay is

$$\zeta_i = \hat{h}_i^* y_{S,R_i} = \hat{h}_i^* \left(\sqrt{E_S} h_i d_0 + \sqrt{E_I} \sum_{j=1}^{M} \beta_{i,j} d_{R_{i,j}} + n_{S,R_i} \right) \quad (11)$$

Now the SINR at the i^{th} relay can be written as

$$\gamma_{S,R_i} = \frac{P_S |\hat{h}_i|^2 \Big/ \left(P_S \sigma_{e_h}^2 + 1\right)}{1 + P_{I_R} \sum_{j=1}^{M} |\beta_{i,j}|^2 \Big/ \left(P_S \sigma_{e_h}^2 + 1\right)} = \frac{U}{1+V} \quad (12)$$

and its PDF can be written as

$$f_{\gamma_{S,R_i}}(\gamma) = \frac{1}{\eta} \left(\frac{1}{\tau}\right)^M \exp\left(-\frac{\gamma}{\eta}\right) \left(\frac{1}{\tau} + \frac{\gamma}{\eta}\right)^{-M} \left(1 + M\left(\frac{1}{\tau} + \frac{\gamma}{\eta}\right)^{-1}\right) \quad (13)$$

Where $\eta = \frac{P_S \Omega_{\hat{h}}}{1 + P_S \sigma_{e_h}{}^2}$,and $\tau = \frac{P_{I_R} \Omega_\beta}{1 + P_S \sigma_{e_h}{}^2}$

The expression for P_{off} can be computed as follows and can be expressed as [4]

$$P_{off} = a \int_0^\infty Q\left(\sqrt{b\gamma}\right) f_{\gamma_{S,R_i}}(\gamma) \, d\gamma \quad (14)$$

Where (a,b) are constants depending on the type of modulation and $Q(.)$ is the Q-function defined as

$$Q(x) = \frac{1}{2\Pi} \int_x^\infty \exp\left(-\frac{u^2}{2}\right) du$$

Now the P_{off} can be expressed as [4], [5],

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 7, July 2013

$$P_{off} = \frac{a}{2}\left(1 - \frac{\sqrt{1-c}}{c^M \tau^M}.\Psi\left(M; M+\frac{1}{2}; \frac{1}{c\tau}\right)\right) \quad (15)$$

where $C = \frac{1}{1+(b\eta/2)}$ and $\Psi(x;y;z)$ is the confluent hypergeometric function of second kind given by [5] $\Psi(x;y;z) = \frac{1}{\Gamma(x)}\int_0^\infty \exp(-zt)t^{x-1}(1+t)^{y-x-1}dt$ by substituting the value of P_{off} into $f_{\gamma_{out}}(\gamma)$, a closed-formexpression for the unconditional PDF of the output SINR, $f_{\gamma_{out}}(\gamma)$, can be obtained. Channel estimation error deteriorates the perfor mance of the system. Function $Q\left(\sqrt{\gamma}\right)$ is depicted to better explain this assertion. It is apparent that, for larger values of γ, the behaviour of the PDF becomes increasingly irrelevant because the Q-function goes to zero so fast that the integrand is almost null throughout almost the whole integration range.The above figure shows the plot for PDF of the output SINR (γ) for different values of estimation error variance and number of relays. we assumed five co-channel interferers with $P_I = P_{I_R} = 0dB$ at $P_S = 12dB$.

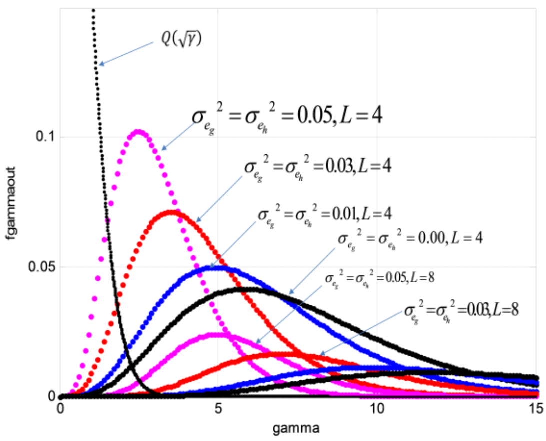

Fig 2. The PDF of the output SINR with four and eight relays in thepresence of five co-channel interferences.

recalling that $Q(0) = 1/2$, the behaviour of the PDF around zero never loses importance. Increased estimation error increases the value of the PDF around zero. On the other hand, as the number of relays increases, the value of the PDF around zero decreases, which would improve the system performance.

B. *Outage Probability*

Another performance measure that is often used to characterize a digital mobile radio system operating in a fading environment in the presence of interference is the outage probability. It may be defined as the probability of unsatisfactory signal reception over the intended coverage area and represents the probability that the signal level in the coverage area falls below a specified SINR γ_T .Equivalently, it represents the probability of the instantaneous BER (Bit error rate) falls above a specified bit error probability P_e^*.Thus, the outage may be expressed as $P_{out} = Pt(\gamma_{out} \le \gamma_T) = \int_0^{\gamma_T} f_{\gamma_{out}}(\gamma)\,d\gamma$ Now, by using $f_{\gamma_{out}}(\gamma)$ the outage probability can be written as

$$P_{out} = \sum_{t=0}^{L}\left(P_{off}\right)^{L-t}\left(1-P_{off}\right)^{t} \left(1-\exp\left(-\frac{\gamma_T}{\lambda}\right)\left(\frac{\left(\frac{1}{\chi}\right)}{\left(\frac{\gamma_T}{\lambda}+\frac{1}{\chi}\right)}\right)^{N}\sum_{k=0}^{t}\frac{\left(\frac{\gamma_T}{\lambda}\right)^{k}}{k!}\sum_{i=0}^{k}\binom{k}{i}\frac{(N)_i}{\left(\frac{\gamma_T}{\lambda}+\frac{1}{\chi}\right)^{i}}\right) \quad (16)$$

In the above equation, if we substitute $\gamma_T = -\frac{1}{\alpha}\ln\left(2P_e^*\right)$ and $\alpha = 1$, then closed form expression for the outage probability in the case of non-coherent or differentially coherent PSK i.e. DPSK system will be obtained. If $\alpha = 1/2$ then closed form expression for the outage probability in the case of non-coherent FSK i.e. NCFSK system will be obtained. We can observe from Fig.3 that, decreasing the channel estimation error improves the system performance in terms of outage probability, for fixed number of interferer's. Therefore in boththe cases i.e. for coherent and in non-coherent detection, decreasing the channel estimation error improves the system performance in terms of outage probability, for fixed number of interferer's.

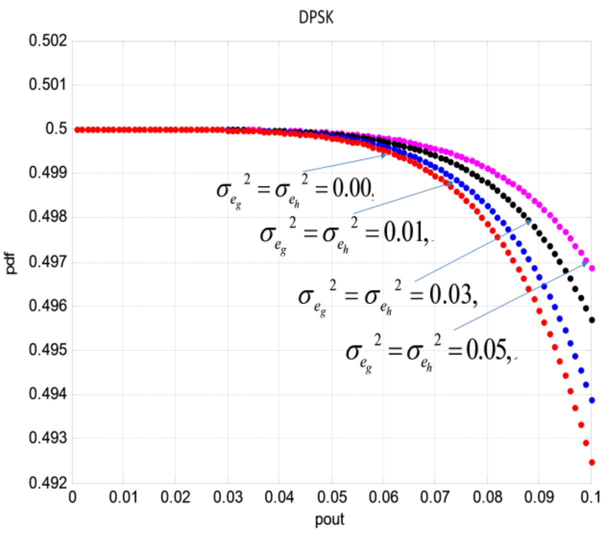

Fig 3. Plot for outage probability versus the threshold BER (Pe*) in case of non-coherent detection for different values of error variances.

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 7, July 2013

Now in the equation of P_{off} if we substitute $\gamma_T = \frac{1}{\alpha} erfc^{-1}\left(2P_e^*\right)$. If $\alpha = 1$, then closed form expression for the outage probability in the case of coherent PSK i.e. BPSK system will be obtained. If $\alpha = 1/2$, then closed form expression for the outage probability in the case of coherent FSK i.e. BFSK system will be obtained.

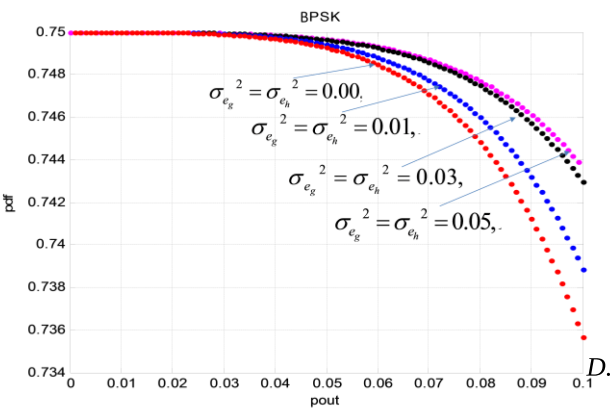

Fig 4. Plot for outage probability versus the threshold BER (Pe*) in case of coherent detection for different values of error variances.

We can observe from graph that, decreasing the channel estimation error improves the system performance in terms of outage probability, for fixed number of interferer's.

C. Average Bit Error Probability (BEP)

The average error probability $\overline{P_e}$, can be derived by averaging the instantaneous error probability $\overline{P}e = \int_0^\infty P_e(\gamma) f_{\gamma_{out}}(\gamma) d\gamma$. $P_e(\gamma)$ is the conditional probability of error in an additive white Gaussian noise (AWGN) channel depending on the type of detection scheme employed.

For non-coherent frequency-shift keying (NCFSK) or a differentially coherent phase-shift keying (DPSK) system, the conditional probability of error for a given SINR γ is given by $P_e(\gamma) = \frac{1}{2}\exp(-\alpha\gamma)$ Where, $\alpha = 1$ for binary PSK $\alpha = 1/2$ for binary FSK. $f_{\gamma_{out}}(\gamma)$ is the PDF at output of the MRC.

Now substituting these in average error probability we get

$$\overline{P}_e = \frac{1}{2}\sum_{t=0}^{L}\left(P_{off}\right)^{L-t}\left(1-P_{off}\right)^t\left(\frac{1}{\chi}\right)^{t+1} \sum_{k=0}^{t+1}\binom{t+1}{k}(N)_k\,\chi^k\Psi\left(t+1, t-N-k+2, \frac{\alpha\lambda}{\chi}+\frac{1}{\chi}\right) \quad (17)$$

For coherent system, it is well known that the conditional probability of error, for a given value of the instantaneous SINR γ, is given by $P_e(\gamma) = \frac{1}{2}erfc\left(\sqrt{\alpha\gamma}\right)$. If we consider modulation constants as a, b then $P_e(\gamma)$ can be written as $P_e(\gamma) = \frac{a}{2}erfc\left(\sqrt{\frac{b\gamma}{2}}\right)$

Now, $\overline{P}e = \int_0^\infty P_e(\gamma) f_{\gamma_{out}}(\gamma) d\gamma$

Now on substituting the values we get,

$$\overline{P}_e = \frac{a}{2}\sum_{t=0}^{L}\left(P_{off}\right)^{L-t}\left(1-P_{off}\right)^t[1-\left(\frac{(1-\mu)^{\frac{1}{2}}}{\mu^N\chi^N}\right) \sum_{k=0}^{t}\binom{2k}{k}\left(\frac{\mu}{4}\right)^k\sum_{i=0}^{k}\binom{k}{i}\frac{(N)_i}{\mu^i}\Psi\left(N+i, N-k+i+\frac{1}{2}, \frac{1}{\mu\chi}\right)] \quad (18)$$

D. Asymptotic Average Symbol Error Probability

Although the expression for the error probability enables numerical evaluation of the system performance and is not computationally demanding, it does not offer insight into the effect of the system parameters. We now aim at expressing $\overline{P_e}$ in a simpler form. Here, we recall that the behaviour of the PDF of the output SINR around the origin can provide simpler (and accurate) forms for the error probability.

1. *Approximate* $f_{\gamma_{S-R_i}}(\gamma)$:This can be approximated using Taylor's series to be expressed as

$$f_{\gamma_{S-R_i}}(\gamma) = \frac{1}{\eta}(1+M\tau)+o(\gamma)$$
$$\to \frac{1+P_S\sigma_{e_h}{}^2}{P_S\Omega_{\hat{h}}}\left(1+M\frac{P_{I_R}\Omega_\beta}{1+P_S\sigma_{e_h}{}^2}\right)+o(\gamma)$$
$$\to \frac{1}{P_S\Omega_{\hat{h}}}\left(1+MP_{I_R}\Omega_\beta+P_S\sigma_{e_h}{}^2\right)+o(\gamma)$$

Where $o(\gamma)$ stands for higher order terms. Therefore P_{off} can be approximated as

$$P_{off} = \frac{a}{2b}\frac{1}{P_S\Omega_{\hat{h}}}\left(1+MP_{I_R}\Omega_\beta+P_S\sigma_{e_h}{}^2\right)+o(\gamma)$$

2. *Approximate* $f_{\gamma_{out|C}}(\gamma)$ *:* for this we use the following Lemma.

Lemma 1*:* Let $X_i, i = 1, 2, \cdots\cdots, T$, be non-negative independent random variables and assume the PDF of X_i to be approximated by $f_{X_i}(x) \approx a_i x^{t_i - 1} + o(x)$

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 7, July 2013

Then the approximate distribution of $Y=\sum_{i=1}^{T} X_i$ is given by

$$f_Y(y)\approx \frac{y^{\sum_{i=2}^{T} t_i-1}}{\Gamma\left(\sum_{t=1}^{T} t_i\right)}\prod_{t=1}^{T}\Gamma(t_i)a_i+o(y)$$

Indeed, $\gamma_{out|C}$ is the summation of the individual SINR's from the direct link and the active indirect links, i.e., $\gamma_{out|C}=\gamma_{out|n=0}+\gamma_{out|n=2}+\cdots\cdots+\gamma_{out|n=|C|}$. Therefore, the PDF of $\gamma_{out|n=i}$ can be written by substituting $|C|=0$ in $f_{\gamma_{out}}(\gamma|c)$

$$f_{\gamma_{out|\,n=i}}(\gamma)=\frac{1}{\lambda}\left(\frac{1}{\chi}\right)^{N}\exp\left(-\frac{\gamma}{\lambda}\right)\left(\frac{1}{\chi}+\frac{\gamma}{\lambda}\right)^{-N}\left(1+\left(\frac{1}{\chi}+\frac{\gamma}{\lambda}\right)^{-1}\right) \quad (19)$$

The approximate PDF of $\gamma_{out|C}$ can be written using Lemma 1, therefore $f_{\gamma_{out|C}}$ can be expressed as

$$f_{\gamma_{out|\,c}}(\gamma)\approx\left(\frac{1}{\lambda}\right)^{|c|+1}\frac{\gamma^{|c|}}{\Gamma(|c|+1)}(1+N\chi)^{|c|+1}+o(\gamma)$$

Now, substituting values of λ and γ we get,

$$f_{\gamma_{out|\,c}}(\gamma)\approx\left(\frac{1}{P_S\Omega_{\hat{g}}}\right)^{|c|+1}\frac{\gamma^{|c|}}{\Gamma(|c|+1)}\left(1+P_S\sigma_{e_g}^{\;2}+NP_I\Omega_\alpha\right)^{|c|+1} \quad (20)$$

Hence, using the approximate p_{off} and approximate PDF of $\gamma_{out|C}$ i.e. , $f_{\gamma_{out|\,c}}$ we can approximate the unconditional PDF of γ_{out} as,

$$f_{\gamma_{out}}(\gamma)\approx\sum_{t=0}^{L}\frac{(P_{off})^{L-t}\gamma^{t}}{\Gamma(t+1)}\left(\frac{1}{P_S\Omega_{\hat{g}}}\right)^{t+1}\left(1+P_S\sigma_{e_g}^{\;2}+NP_I\Omega_\alpha\right)^{t+1}$$

Therefore now approximate error probability can be given by $\bar{P}_e=a\int_0^{\infty} f_{\gamma_{out}}(\gamma)Q\left(\sqrt{b\gamma}\right)d\gamma$

$$\bar{P}_e=a\sum_{t=0}^{L}\frac{(P_{off})^{L-t}2^{t}\Gamma\left(t+\frac{3}{2}\right)}{\sqrt{\pi}b^{t+1}(t+1)!}\left(\frac{1}{P_S\Omega_{\hat{g}}}\right)^{t+1}\left(1+P_S\sigma_{e_g}^{\;2}+NP_I\Omega_\alpha\right)^{t+1} \quad (21)$$

Two inferences can be drawn from the equation (21). First, if the estimation error does not depend on P_S and assuming that there is no co-channel interference, then we can observe error floors (constant region in the graphs). From equation (21) if we neglect first term then that error probability will not be a function of P_S and hence independent i.e. error probability does not improve even though we increase P_S. Secondly, if we assume a perfect channel estimation i.e. $\sigma_{e_g}^{\;2}=0$ and the impairments are only in terms of co-channel interference. Hence, the interference power will be high i.e. the term $NP_I\Omega_\alpha$ will be increasing in the same level of $P_S\Omega_{\hat{g}}$. Therefore the ratio $NP_I\Omega_\alpha/P_S\Omega_{\hat{g}}$ remains constant and the error floors are observed.

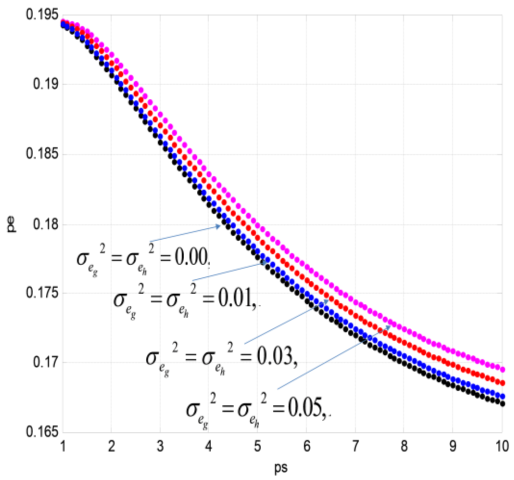

Fig 5.Plot shows the asymptotic probability versus (in dB).

Furthermore, from the above graph in the low-to-medium range of *Ps*, we can see that increasing *Ps* improves the error performance because the dominant noise in said region is the AWGN. Provides results that are tight only in the medium to-high *Ps* range. On the other hand, at high *Ps*, error floors appear due to the co-channel interferences and imperfect estimations which are independent of *Ps*.

REFERENCES

[1] H. Yu, I.-H. Lee, and G.Stuber, "Outage Probability of Decode-and-Forward cooperative relaying systems with co-channel interference," *IEEE Trans. Wireless Commun.*, vol. 11, no. 1, pp.266-274, Jan. 2012.

[2] X. J. Zhang and Y. Gong, "On the diversity gain in dynamic decode-and-forward channels with imperfect CSIT," *IEEE Trans. Wireless Commun.*, vol. 59, no. 1, pp.59-63, Jan. 2011.

[3] S.S. Ikki, S.Aissa,"Impact of Imperfect Channel Estimation and Co-channel Interference on Regenerative Co-operative networks" *Wireless Communications Letter IEEE (Volume:1 Issue:5)*

[4] V.A.Aalo and J. Zhang,"Performance analysis of maximal ratio combining in the presence of multiple equal-power co-channel interferers in a Nakagami fading channel," *IEEE Trans.Veh Technol.*, vol. 50, No.5, pp.497-503,Mar.2001.

[5] I.S. Gradshteyn and I.M. Ryzshik, *Table of Integrals, Series and Products,* 7th edition. Academic Press,2007.

[6] *Handbook of Mathematical Functions*, Dover, NY, 1970.

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ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 7, July 2013

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