A Novel Selection Combining Technique for Multi relay Cooperative Communication System Using Decode and Forward Protocol

K.Kavitha , A.Kumaresan

Associate Professor , Assistant Professor
Department of ECE, Kumaraguru College of Technology, Coimbatore, India

Abstract— **The wireless data communication system demands robust methodologies to combat the effect of fading to increase the throughput. The paper proposes a novel selection combining algorithm for multi relay cooperative system using decode and forward algorithm. Cooperative communication is one of the promising diversity techniques which have attracted the attention of the researchers currently. In the conventional cooperative communication system, the data is transmitted through 'N' number of relays to the destination. The signals received from all the relays are combined to decode the data at the destination.. In Literature, there are various combining schemes such as equal gain combining, maximum ratio combining scaled selection combining techniques. In the conventional selection combining, only one relay signal is selected based on its channel state information (CSI). In this, the source to relay CSI is not utilized. It has been proved that by utilizing full CSI the error performance could be improved of the selection combining algorithm. In the proposed system, instantaneous signal to noise ratio (SNR) is calculated at the relay stations and it is used to take the decision whether to decode the signal and forward (DF) the same to destination or to be dropped. Only the signals with SNR above the threshold from the received relay signals is considered for combining. The performance of the proposed system with maximum ratio combining and scaled selection combining has been analyzed. In this system the error performance is improved by using selected relay signal, whereas only one relay is used in the conventional selection combining system.**

Index Terms—Decode and forward (DF), M-ary phase-shift keying (MPSK), Rayleigh fading, Threshold selection combining, Symbol error probability (SEP).

I.INTRODUCTION

Diversity combining technique is one of the efficient methods formulated against Fading in wireless Communication. In this cooperative diversity, users in this network will share their antennas or resources to provide diversity. Most commonly using diversity technique is spatial diversity which involves multiple antennas which be used with enough distance separation between them. So that the receiver can receive multiple independently fading signal paths. By focusing on this problem we came across with one alternative which involves the distributed space diversity named as Cooperative Communication. At the base station , Spatial diversity is obtained by combining the same information bearing signals from the different physically separated mobile units[1].Several protocols are proposed in the literature for implementing user co-operation, from which the decode-and-forward (DF) protocol is used in the paper. In the DF protocol, the relays decode and forward the source's data to the destination [2] .The impact of channels state information (CSI) of the source-to-relay link and the relay-to-destination link on various relay selection cooperative schemes has been presented in [3]. In [4],an optimum threshold that minimizes the end-to-end bit error probability, has been analyzed for a single-relay cooperative system. A two-relay distributed switch and stay combining has been proposed with amplify and forward and DF protocols and the outage error analysis has been presented in [5].In [6],the error performance of a single-relay cooperative diversity system with DF relaying has been studied, and this work consider that the relay forwards the source's data only if the instantaneous signal-to-noise (SNR) is above a threshold. In[7],[8], the performance analysis of multi-relay cooperative diversity with DF protocol and without threshold relaying has been investigated. The outage performance of selection DF cooperative relay networks has been analyzed in [9] for Rayleigh fading and in[10] for Nagakami Fading. In [11],the M-ary PSK error performance of a single-relay cooperative diversity system with selection combining (that does not include the effect of the source-to-relay link) has been presented using a new paired error approach. In this paper, instantaneous signal to noise ratio (SNR) is calculated at the relay stations and it is used to take the decision whether to decode the signal and forward (DF) the same to destination or to be dropped. Only the signal with SNR above the threshold from the received relay signals is considered for combining. The performance of the proposed system versus Non cooperation signal and scaled selection combining has been analyzed. In this paper, we consider a cooperative diversity system which has a source, multiple relays and destination in a flat Rayleigh fading environment with statically independent links. The main drawback of the usual instantaneous SNR-based selection combining with DF protocol for selection between the source-to-destination and relay-to-destination links is that it does not incorporate the effect of the source-to-relay link, that is the interuser link which plays a important role in the error performance analysis. To overcome this problem, we present here a deterministic scaled factor, which incorporates the effect of source-to-relay fading . We derived the end-to-end symbol error probability (SEP) of this scheme for binary PSK (BPSK) in closed-form, we also give a method of optimizing the scale factor such that it minimizes the end-to-end SEP.

II.SYSTEM MODEL

In this paper, we consider a cooperative diversity system which has a source, multiple relays and a destination in a flat Rayleigh fading environment with statically independent links (Fig.1).

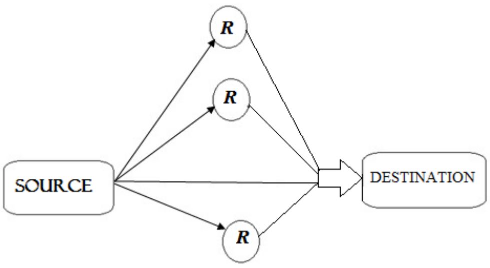

Fig.1.Multiple relaying path

The binary information is modulated by M-ary PSK modulator and broadcasted to destination as well as to the relay over flat fading environment. This is carried out by 2 phases of operation in progress with this diversity scheme. In first phase, source will broadcast the BPSK signal to the destination and as well as to the relays in the fading environment. The complex baseband signal received at the corresponding destination and at the relays. The received signal is demodulated and detected using DF algorithm. Let the information carrying complex signal have energy 2Es to the constellation S, which is refers to symbol and it is given by,

$$S_m = \sqrt{2E_s}\, \exp\left(\frac{j2\pi(m-1)}{M}\right), \quad m=1,2,3,\ldots..M$$

Where, $j = \sqrt{-1}$

The complex baseband received signal at the destination and at the relay at the first time slot is represented as,

$$r_{sd} = h_{sd}.S + n_{sd}$$

$$r_{sr} = h_{sr}.S + n_{sr}$$

Where h_{sd} and h_{sr} are the random complex fading gains of the source to destination (SD) link and source to relay (SR) link. Further, the additive white Gaussian noises of the source to destination and source relay links are n_{sd}, n_{sr} respectively. Whereas the fading gains are formed as symmetric Gaussian random variable with zero Mean and Variance Ωsd and Ω_{sr} respectively. The noises are formed as zero mean complex Gaussian random variable with the variance $2N_o$.

In second Phase, the relay regenerate the symbol $\hat{s}$ and transmit to the destination. The destination receives the relay signal as,

$$r_{rd} = h_{rd}.\hat{s} + n_{rd}$$

where hrd and nrd are fading gains and additive white Gaussian noise of the Relay Destination link respectively. We assume that the destination have knowledge about the channel state information (CSI) of all links including relay to destination and source to destination, Meanwhile relay has the CSI of SR link.
Now we indicate the instantaneous SNRs of the SD, SR, and the RD links, respectively as

$$\Upsilon sd = \frac{Es}{No}\left|h_{sd}^2\right|, \Upsilon sr = \frac{Es}{No}\left|h_{sr}^2\right|, \ \Upsilon rd = \frac{Es}{No}\left|h_{rd}^2\right|$$

The corresponding average SNRs are given by,

$$\Gamma_{sd} = E[\Upsilon_{sd}] = \frac{E_S\ \Omega_{sd}}{N_O} ,$$

$$\Gamma_{sr} = E[\Upsilon_{sr}] = \frac{E_S\ \Omega_{sr}}{N_O},$$

$$\Gamma_{rd} = E[\Upsilon_{rd}] = \frac{E_S\ \Omega_{rd}}{N_O} .$$

Where, Γth is known as assigned average SNR threshold value and E [.] is known as expectation operator. The destination detects received signal $\check{S}$ and finally detected symbol is obtained from the proposed decision rule is,

$$\check{S} = \begin{cases} \arg\left\{\begin{matrix}\max \\ s \in S\end{matrix} Re(S^* h_{SD}^* \Upsilon_{SD})\right\} \\ \arg\left\{\begin{matrix}\max \\ s \in S\end{matrix} Re(S^* h_{SR}^* \Upsilon_{SR})\right\} \\ \arg\left\{\begin{matrix}\max \\ s \in S\end{matrix} Re(S^* h_{RD}^* \Upsilon_{RD})\right\} \end{cases}$$

$\check{S}$ partial to the following conditions,

$$\begin{cases} if\ \ \Upsilon_{SD} > \Gamma_{th} \ , \\ if\ \ \Upsilon_{SD} < \Gamma_{th} \ \text{ and } \Upsilon_{SR} > \ \Upsilon_{RD}, \\ if\ \ \Upsilon_{SD} < \Gamma_{th} \ \text{ and } \Upsilon_{SD} > \ \Upsilon_{RD}. \end{cases}$$

In this system we compared our proposed performance with the conventional schemes. Which articulates different combining schemes nurtured together to novel multiple selection combining scheme.

In previous conventional selection combining and threshold selection combining schemes out of N signal random signal is took for analysis and decision purpose. But in this proposed combining scheme (Hybrid of threshold and selection combining scheme) we enhanced the performance by use of dual threshold level process. At the destination we formulate selection combining scheme for best performance from received signal $\check{S}$.

III.PERFORMANCE ANALYSIS

We represent the instantaneous SNR as,

$$\Upsilon = \frac{Es}{No}|h|^2,$$

In this section, we use the mathematical probability model for DF relaying proposed in [4] to derive a closed-form expression for the outage probability of the SC system.

The conditional error probability for MPSK is given by,

$$P_e(\Upsilon) = \frac{1}{\pi}\int_0^{\frac{\pi(M-1)}{M}} \exp\left(-\frac{\Upsilon \sin^2\frac{\pi}{M}}{sin^2\emptyset}\right)$$

A. SEP for Source-Destination link

The probability of error in SD link is derived in the form under the condition $\Upsilon_{SD} > \Upsilon_{Th}$ or $\Upsilon_{SD} > \Upsilon_{RD}$ is given by,

$$P_{eSD1} = \int_{\Gamma_{th}}^{\infty} \frac{1}{\pi} \int_0^{\frac{\pi(M-1)}{M}} exp\left(-\frac{\Upsilon \sin^2\frac{\pi}{M}}{sin^2\emptyset}\right) \times \left(\frac{1}{\Gamma_{SD}}\right) exp\left(-\frac{x}{\Gamma_{SD}}\right) dxd\emptyset$$

Simplify error probability equation by applying integral over x,

$$P_{eSD1} = \frac{1}{\pi\Gamma_{SD}} \int_0^{\frac{\pi(M-1)}{M}} \frac{1}{\left(\frac{\sin^2\frac{\pi}{M}}{sin^2\emptyset}+\frac{1}{\Gamma_{SD}}\right)} \times exp\left(-\left(\frac{\sin^2\frac{\pi}{M}}{sin^2\emptyset}+\frac{1}{\Gamma_{SD}}\right)\right)\Gamma_{th} d\emptyset$$

Probability of error in source to destination link $\Upsilon_{SD} > \Upsilon_{RD}$ is obtained by applying integral over x and further substitution we get total symbol error probability of S-D link is given as,

$$\boldsymbol{P_{eSD}} = \frac{\mathbf{1}}{\boldsymbol{\Gamma_{SD}}} \boldsymbol{\rho_{2(\Gamma_{SD},\emptyset_0)}} - \boldsymbol{\rho_{1(\Gamma_{SD},\emptyset_0,\Gamma_{th})}} - \boldsymbol{\rho_{4(\Gamma_{SD},\Gamma_{RD},\emptyset_0)}} + \boldsymbol{\rho_{3(\Gamma_{SD},\Gamma_{RD},\emptyset_0,\Gamma_{th})}}$$

B. SEP for Source-Relay-Destination Link

The probability of error in R-D (Relay-Destination) link, under the condition of $\Upsilon_{sd} < \Upsilon_{rd}$ is given by ,

$$P_{eRD} = \int_z^{\infty} \int_0^{\Gamma_{th}} \int_0^{\infty} p_e(y,z) \frac{1}{\Gamma_{SD}} exp\left(-\frac{x}{\Gamma_{SD}}\right) \times \left(\frac{1}{\Gamma_{RD}}\right) exp\left(-\frac{y}{\Gamma_{RD}}\right) \frac{1}{\Gamma_{SD}} exp\left(-\frac{z}{\Gamma_{SD}}\right) dzdxdy$$

Lets define $P_{eRD1}, P_{eRD2}, P_{eRD3}$

$$P_{eRD1} = \left(\frac{1}{\Gamma_{SR}}\right) \rho_2(\Gamma_{SR}, \emptyset_0) \int_x^{\infty} (1\ (y)) \times \left(\frac{1}{\Gamma_{RD}}\right) exp\left(-\frac{y}{\Gamma_{RD}}\right) dy$$

$$P_{eRD2} = \int_0^{\infty} P_e(y) \frac{1}{\Gamma_{SR}} exp\left(-\frac{z}{\Gamma_{SR}}\right) dz$$

$$P_{eRD3} = \sum P_{l,k}(y) \int_0^{\infty} P_{k,l}(z) \frac{1}{\Gamma_{SR}} exp\left(-\frac{z}{\Gamma_{SR}}\right) dz$$

$P_{l,k^{(z)}}$ is probability of error in S-R link when S_k is transmitted in S-R link and it is detected as S_l at the relay node. $P_{k,l^{(y)}}$ is probability of error in R-D link when S_l is transmitted from relay to destination and it is detected as Sk at the destination node.

By solving above equations we get,

$$P_{eRD1} = (1 - P_e(y)) \frac{1}{\pi} \int_0^{\frac{\pi(M-1)}{M}} \int_0^{\infty} \frac{1}{\Gamma_{SR}} \times exp\left(-\left(\frac{\sin^2\frac{\pi}{M}}{sin^2\emptyset}+\frac{1}{\Gamma_{SR}}\right)\right) zdzd\emptyset$$

Now applying integral over y in as,
By Substituting $p_{e(y)}$ we get,

$$P_{eRD1} = \left(\frac{1}{\Gamma_{SR}}\right)\rho_2(\Gamma_{SR},\emptyset_0) \times \left(\frac{1}{\Gamma_{RD}}\right) \times \quad exp\left(-\frac{x}{\Gamma_{RD}}\right)\int_0^{\frac{\pi(M-1)}{M}} \frac{1}{\left(\frac{\sin^2\frac{\pi}{M}}{sin^2\emptyset}+\frac{1}{\Gamma_{RD}}\right)}\, exp\left(-\left(\frac{\sin^2\frac{\pi}{M}}{sin^2\emptyset}+\frac{1}{\Gamma_{RD}}\right)\right)xd\emptyset$$

By applying integral over x and by further substitution, we get total symbol error probability of R-D link is given as

$$\boldsymbol{P_{eRD}} = \sum_{l=1, l\neq k}^{M} \frac{1}{4\pi\Gamma_{SD}\Gamma_{SR}}[\rho_2(\Gamma_{SR},\emptyset_1) - \quad \rho_2(\Gamma_{SR},\emptyset_2)] \times (\boldsymbol{P1} - \boldsymbol{P2})$$

Where, P1 and P2 is given as,

$$P1 = \int_0^{\pi-\emptyset_3} \frac{1}{\left(\frac{\sin^2\emptyset_4}{sin^2\emptyset}+\frac{1}{\Gamma_{RD}}\right)} \frac{1}{\left(\frac{\sin^2\emptyset_3}{sin^2\emptyset}+\frac{1}{\Gamma_{RD}}+\frac{1}{\Gamma_{SD}}\right)} \times \quad \left(1 - exp\left(-\left(\frac{\sin^2\emptyset_3}{sin^2\emptyset}+\frac{1}{\Gamma_{RD}}+\frac{1}{\Gamma_{SD}}\right)\right)\Gamma_{th}\right)d\emptyset$$

$$P2 = \int_0^{\pi-\emptyset_4} \frac{1}{\left(\frac{\sin^2\emptyset_4}{sin^2\emptyset}+\frac{1}{\Gamma_{RD}}\right)} \frac{1}{\left(\frac{\sin^2\emptyset_4}{sin^2\emptyset}+\frac{1}{\Gamma_{RD}}+\frac{1}{\Gamma_{SD}}\right)} \times \quad \left(1 - exp\left(-\left(\frac{\sin^2\emptyset_4}{sin^2\emptyset}+\frac{1}{\Gamma_{RD}}+\frac{1}{\Gamma_{SD}}\right)\right)\Gamma_{th}\right)d\emptyset$$

IV.NUMERICAL RESULTS

In this section, we discuss about the error analysis using DF relaying protocol and Symbol error probability (SEP) measure is carried out . Plots are done for received signal SEP with varying average SNR the decision rule. Fig.2, shows that the results for Non cooperation, conventional Scaled selection combining and Threshold switching selection combining for multiple threshold combining schemes with the outage probability error measure for various instantaneous SNR values of BPSK.

In this evaluated result we use switched threshold decision rule for error performance analysis, which proved as better combining scheme for multiple relay with the better error reduction.

Fig 2, shows that the BER performance of proposed scheme is improved to the conventional selection combining. Schemes, In this proposed scheme, we fixed a threshold value at each relay station and at the destination station. Based upon the instantaneous SNR we took proper decision to forward the desired signal for proper filtering and combining at receiver node. The above plot shows that the multiple thresholds combining scheme provides better error performance than existing schemes with achieved gain of 15dB over other schemes from non-cooperative schemes.

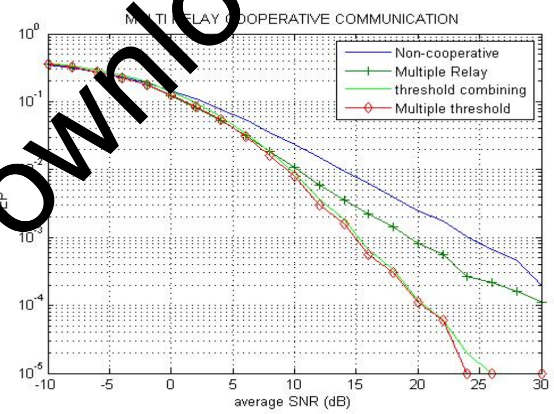

Fig 2. BER performance for BPSK Signalling for multiple threshold scheme for multiple relays

CONCLUSION

In this paper, we proposed the threshold switching technique which incorporates the effect of source to relay link to reduce the probability of error. The end to end symbol error probability is derived for M-PSK signalling with DF relaying in flat Rayleigh fading. We have proved that the BER of proposed scheme is reduced than conventional non-cooperation and scaled selection combining schemes for multiple relays with multiple threshold combining scheme.

ACKNOWLEDGEMENT

The authors thank the management and principal of Kumara guru College of Technology, Coimbatore for providing excellent computing facilities and encouragement.

REFERRENCE

[1] A.Sendonaris, E.Erkip, and B.Aazhang, “User cooperation diversity – part I: system description,” IEEE Transactions on Communications, vol. 51, no. 11, pp. 1927–1938, November 2003.

[2] J.N.Laneman, D.N.C.Tse, and G.W.Wornell, “Cooperative diversity in wireless networks: efficient protocols and outage behavior,” IEEE Transactions on Information Theory, vol. 50, no. 12, pp. 3062-3080, December 2004.

[3] M.D.Selvaraj and R.K.Mallik, ”Error analysis of decode-and-forward protocol with selection combining,” IEEE Transactions on Wireless Communications, vol. 8, no.6, pp. 3086-3094, June 2009.

[4] F. A. Onat, Y. Fan, H. Yanikomeroglu, and J. S. Thompson, Asymptotic BER analysis of threshold digital relaying schemes in cooperative wireless systems,”, IEEE Trans. Wireless Commun., vol. 7, no. 12, pp. 4938-4947, Dec. 2008.

[5] M.D.Selvaraj and R.K.Mallik, Single-Relay Cooperative Diversity with Scaled Selection Combining, IEEE Transactions on Communications,vol. 59, no.3, pp. 3086-3094, March 2011.

[6] F. A. Onat, A. Adinoyi, Y. Fan, H. Yanikomeroglu, J. Thompson, and I. Marsland, Threshold selection for SNR-based selective digital relaying in cooperative wireless networks, IEEE Trans. Wireless Commun., vol. 7, no. 11, pp. 42264237, Nov. 2008.

[7] F. A. Onat, A. Adinoyi, Y. Fan, H. Yanikomeroglu, and J. S. Thompson, Optimum threshold for SNR-based selective digital relaying schemes in cooperative wireless networks, in Proc. IEEE Wireless Communications and Networking Conference (WCNC), 2007.

[8] W. P. Siriwongpairat, T. Himsoon, W. Su, and K. J. R. Liu, Optimum threshold-selection relaying for decode-and-forward cooperation protocol,” in Conf. Rec. IEEE Wireless Commun. Netw. Conf., vol. 2, Apr. 2006, pp. 1015-1020.

[9] T. Eng, N. Kong, and L. B. Milstein, Comparison of diversity combining techniques for Rayleigh-fading channels, IEEE Trans. Commun., vol. 44, no. 9, pp. 11171129, Sep. 1996.

[10] C.C.Tan and N.C.Beaulieu, ”Infinite series representations of the bivariate rayleigh and Nakagami-m distributions,” IEEE Transactions on Communications,vol. 45, no. 10, pp. 1066-1073, October 1997.

[11] R.K.Mallik and M.Z.Win, ”Analysis of hybrid selection/ maximalratio combining in correlated Nakagami fading,” IEEE Transactions on Comm.., vol. 50,no. 8, pp. 1372-1383, August 2002.[12] T. Eng, N. Kong, and L. B. Milstein, “Comparison of diversity combining techniques for Rayleigh fading channels,” *IEEE Trans. Commun.*, vol. 44, pp. 1117–1129, Sept. 1996.

[13] J. Lu, T. T. Tjhung, and C. C. Chai, “Error probability performance of L-branch diversity reception of MQAM in Rayleigh fading,” *IEEE Trans. Commun.*, vol. 46, pp. 178–181, Feb. 1998.

[14] M. Schwartz, W. R. Bennett, and S. Stein, *Communication Systems and Techniques*. New York: McGraw-Hill, 1966, ch. 10.

[15] M. D. Yacoub, *Foundations of Mobile Radio Engineering*. Boca Raton, FL: CRC Press, 2003.

[16] K.-T.Wu and S.-A. Tsaur, “Selection diversity for DD-SSMA communications on Nakagami fading channels,” *IEEE Trans. Veh. Technol.*, vol. 43, pp. 428–438, Aug. 2007.