Sindh Univ. Res. Jour. (Sci. Ser.) Vol.47 (1): 53-56 (2015)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Performance Analysis of Dual Hop Networks Based on Best Relay Selection

S. I. SIDDIQUI[++], G. AHMAD, S. M. FAHEEM, F. ALI, M. ASHRAF

Department of Electrical Engineering, University of Engineering and Technology, Peshawar

Received 8th June 2014 and Revised 3rd January 2015

Abstract: The main factors that resulted in the popularity of current wireless systems are low transmit power, improved quality of service (QoS), better coverage, more capacity, spatial diversity and high data rates. To address such issues, dual-hop relaying is a promising technique for wireless communication.

In the present study, the performance of dual-hop amplify and forward multiple relay cooperative diversity network with best relay selection has been investigated, where direct and indirect links are used for communication between the source and destination. Only the performance of best relay has been considered which participated in the transmission alone. The relay node that achieved the highest SNR at the destination has been selected as the best relay. The results indicate that full diversity order can be achieved with a single relay with fewer resources.

Keywords: Dual hop, amplify and forward, spatial diversity, cooperative diversity, outage probability

1. INTRODUCTION

Spatial diversity has provided a fascinated interest in order to reduce signal level fluctuation caused by fading. In many cases it is not possible in mobile phones to use several antennas due to a number of constraints, so another type of spatial diversity was introduced by Laneman in (2004) referred to as cooperative diversity that creates spatial diversity in a distributed manner. In cooperative communication, mobile phone creates virtual Multiple Inputs Multiple Outputs (MIMO) system that relays each other's message (Janani, *et al.* 2004). In order to improve reliability and efficiency, an idea of hybrid system was introduced in which MIMO technique was applied to ad hoc relay networks that combined the benefits of MIMO system and ad hoc network (Yijia, and John, 2007).

2. MATERIALS AND METHODS

2.1 Technical Background

Spatial diversity is a leading candidate to handle the fading problems, because of its straight forward adaptability to other forms of diversity i.e. frequency and time diversity (Theodore, 2002). Cooperative diversity is a special type of spatial diversity which is created in a virtual format with the collection of allocated antennas each belonging to independent nodes having their own data to transmit. It has two basic features. Firstly, that the transmitted signal is not only received at the intended destination but also to the nearby nodes. Secondly, the nearby nodes act as individual distributed antennas that lead to the generalization of multiple antenna system (Salama, and Mohamed, 2008).

In cooperative communication, wide area cellular network and ad hoc network are combined together where the nodes in ad hoc network provide transmit diversity to source and destination that may increase the quality of services (bit error rate, block error rate and outage probability measured at physical layer) via cooperation (Aria, and Ahmadreza, 2004). Hence, it exploits the benefit of MIMO in different scenario at lower cost and better performance (Abdulhadi, *et al.* 2010).

2.2 Related Work

Nabar, *et al*. have investigated the performance of two hop diversity network over fading relay channel. Analysis shows that if proper power control is in use, complete spatial diversity can be obtained (Nabar, *et al*. 2004). The performance of two hop regenerative and non-regenerative system over Rayleigh fading for single relay channel (Hasna, *et al*. 2003) and for multiple relays (Anghel, and Kaveh, 2004) have been explored separately. The results showed that at low SNR, regenerative systems outperform non-regenerative but in the high average SNR scenario, both are almost the same.

Experimental evidence supports that regenerative relay systems outperform the non-regenerative relay systems for multi-hop systems with large number of hops (Hasna, and Alouini, 2003). It was inferred that when the relay is in line of sight with the source rather than the destination, the performance of the system is improved (Majhi, *et al*. 2010). The selection

[++]Corresponding Author *Salman Ilahi Siddiqui email:* salman.ilahi@uetpeshawar.edu.pk 0092-91-9216498

cooperation accomplishes full diversity order and offers improved performance because the relay does not desecrate power by transmitting over lossy channel. Results show that practically geographical distributed nodes provide better improvement for the channels whose quality is degraded by shadowing and attenuation (Beres, and Adve, 2008).

2.3. Proposed Model

Our system model is shown in **(Fig. 1)**, consisting of a source node 'S', destination node 'D' and a number of cooperating relay nodes Ri (i=1,2….,M). 'S' communicates with 'D' directly over a channel having Rayleigh fading coefficient $h_{S,D}$. Also 'S' communicate with 'D' via set of K relays using AF protocol, our goal is to select one relay out of the set of K relays in order to retransmit the signal from source to destination. The Rayleigh fading channel coefficients between 'S' and relay Ri are h_{S,R_i} and between relay Ri and 'D' are $h_{R_i,D}$. These all channel coefficients and are considered mutually independent and non-identical .

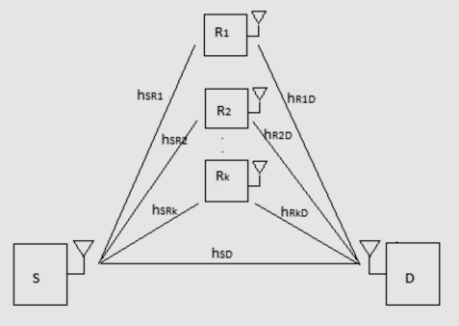


Fig. 1: Opportunistic relaying system model

AF protocol is used for indirect link having an end-to-end SNR given by (Salama, and Mohamed, 2008).

$$\gamma_{S,R_i,D} = \frac{\gamma_{S,R_i} \cdot \gamma_{R_i,D}}{\gamma_{S,R_i} + \gamma_{R_i,D} + 1} \quad (1)$$

where, $\gamma_{S,R_i} = \left|h_{S,R_i}\right|^2 \frac{E_S}{N_o}$ and $\gamma_{R_i,D} = \left|h_{R_i,D}\right|^2 \frac{E_S}{N_o}$ are the instantaneous SNRs between source 'S' and relay *'R_i'* and between relay *'R_i'* and destination 'D' respectively.

The relay which provides highest end-to-end SNR at receiver is considered for retransmitting source signal to destination. If maximum ratio combiner (MRC) technique at 'D' is used then the resultant SNR at 'D' can be written as (Salama, and Mohamed, 2008)

$$\gamma_t = \gamma_{S,D} + \max_{i \epsilon M} \frac{\gamma_{S,R_i} \cdot \gamma_{R_i,D}}{\gamma_{S,R_i} + \gamma_{R_i,D} + 1} \quad (2)$$

where, $\gamma_{S,D} = \left|h_{S,D}\right|^2 \frac{E_S}{N_o}$ is the instantaneous SNR between source 'S' and destination 'D'.

The tight upper bound for $\gamma_{S,R_i,D}$ can be expressed as (Salama, and Mohamed, 2008)

$$\gamma_i = \gamma_{S,R_i,D} \leq min(\gamma_{S,R_i} \,.\, \gamma_{R_i,D}) \quad (3)$$

The PDF of the instantaneous SNR $'\gamma_i'$ can be written in terms of average SNR from 'S' to Relay *'R_i'* $\overline{\gamma}_{S,R_i} = E\left(h_{S,R_i}^2\right)\frac{E_S}{N_o}$ and from *'R_i'* to 'D' $\overline{\gamma}_{R_i,D} = E\left(h_{R_i,D}^2\right)\frac{E_S}{N_o}$ as where $\overline{\gamma_i} = \frac{\overline{\gamma}_{S,R_i}\overline{\gamma}_{R_i,D}}{\overline{\gamma}_{S,R_i} + \overline{\gamma}_{R_i,D}}$ using the value of γ_i in equation (2), the total SNR can be rewritten as

$$\gamma_t \leq \gamma_{S,D} + \gamma_b \quad (4)$$

This approximation is accurately enough specially on medium and high SNR values. Our final results are established with the help of Monte Carlo simulations.

2.4 Analysis and Equations

The error probability for a multi-channel coherent reception can be calculated

$$P\left(e\middle|\gamma_{S,D},\gamma_b\right) = A\, erfc\left(\sqrt{\beta\left(\gamma_{S,D} + \gamma_b\right)}\right) \quad (5)$$

where, $\gamma_{S,D}$, γ_b are SNR values of direct and indirect links respectively and *erfc(.)* is referred to as error function. It is expressed in terms of Gaussian probability integral as (Telatar, 1999)

$$erfc(x) = \frac{2}{\pi}\int_0^{\pi/2} exp\left(-\frac{x^2}{sin^2(\theta)}\right) d\theta \quad (6)$$

From (6), the error probability in (5) can be expressed as:

$$P\left(e\middle|\gamma_{S,D},\gamma_b\right) = \frac{2}{\pi}\int_0^{\pi/2} exp\left(\frac{-\beta\gamma_f}{sin^2(\theta)}\right) exp\left(\frac{-\beta\gamma_b}{sin^2(\theta)}\right) d\theta \quad (7)$$

Also it is assumed that random variables are independent, the joint PDF $f_{\gamma S,D,\gamma b}\left(\gamma_{S,D},\gamma_b\right)$ can be written as $f_{\gamma S,D}\left(\gamma_{S,D}\right) f_{\gamma b}(\gamma_b)$. Therefore the error probability can be expressed as :

$$P(e) = \iint_0^{\infty} P\left(e\middle|\gamma_{S,D},\gamma_b\right) f_{\gamma_{S,D}}\left(\gamma_{S,D}\right) f_{\gamma_b}(\gamma_b) d\gamma_{S,D} d\gamma_b \quad (8)$$

By substituting (7) into (8), we get

$$P(e) = \iint_0^{\infty} \frac{2}{\pi}\int_0^{\pi/2} exp\left(\frac{-\beta\gamma_f}{sin^2(\theta)}\right) exp\left(\frac{-\beta\gamma_b}{sin^2(\theta)}\right) f_{\gamma_{S,D}}\left(\gamma_{S,D}\right) f_{\gamma_b}(\gamma_b) d\theta d\gamma_{S,D} d\gamma_b \quad (9)$$

As the order of integration can be interchange (Telatar, 1999) so, the error probability in (9) can be written as:

$$P(e) = \frac{2}{\pi}\int_0^{\pi/2} M_{\gamma_{S,D}}\left(\frac{\beta}{sin^2(\theta)}\right) M_{\gamma_b}\left(\frac{\beta}{sin^2(\theta)}\right) d\theta \qquad (10)$$

where,

$$M_{\gamma_{S,D}} = \int_0^{\infty} f_{\gamma S,D}(\gamma_{S,D})\ exp(-\gamma_{S,D}) d\gamma_{S,D}$$

$$M_{\gamma_b} = \int_0^{\infty} f_{\gamma b}(\gamma_b)\ exp(-\gamma_b) d\gamma_b$$

represent the MGF of direct link SNR i.e. $\gamma_{S,D}$ and indirect link (relay) SNR i.e. γ_b respectively.

The outage probability for best antenna selection can be written as (Salama, and Mohamed, 2008)

$$P_{out} = P_r(1 \leq R) \qquad (11)$$

It can be seen that P_{out} is actually the CDF of γ_t evaluated at $2^{2R} - 1$, thus

$$P_{out} = F_{\gamma t}(2^{2R} - 1) \qquad (12)$$

where $F_{\gamma t}$ is the CDF of the total end-to-end SNR using the opportunistic relaying in cooperative diversity and can be obtained as shown (Telatar, 1999)

$$F_{\gamma t}(\gamma) = \mathcal{L}^{-1}\left[\frac{M_{\gamma S,D}(S) M_{\gamma b}(S)}{S}\right]_{S=\gamma} \qquad (13)$$

3. RESULTS AND DISCUSSION

The following graphs are plotted in terms of bit error rate (BER) and outage probability versus the average signal to noise ratio (SNR) It is observed from **(Fig.2)** that the outage probability is decreasing when increasing the number of relays. This means that required outage probability is

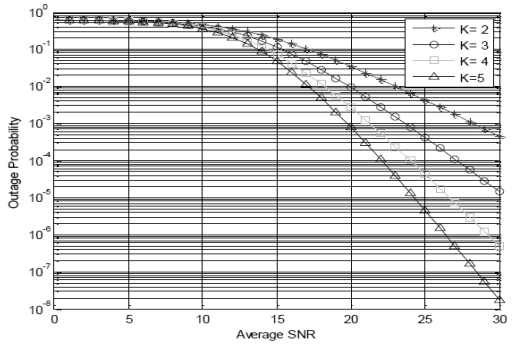


Fig. 2: Outage probability vs Average SNR for our system at end-to-end spectral efficiency R=1bps/Hz, for balanced link ($\overline{\gamma_1} = \overline{\gamma_2}$) and the direct link SNR $\overline{\gamma_o}$ = 3db

achieved at a smaller value of SNR if we keep the number of relays large enough e.g. for K=5 the outage probability of 10^{-5} is achieved by the system at the SNR of approximately 24db but the same outage probability is achieved by the system with K=4 at an SNR of approximately 27db.

It can be observed from **(Fig. 3)** that the outage performance is getting better with unbalanced link compared to the balanced link. As the number of relays increases from 2 to 5 in unbalanced link, its outage probability decreases more as compared to the balanced link. We observe that the outage performance of unbalanced link is better than the balanced link by the comparison of Fig. 2 and 3. It is noticed that the improvement in any single link can notably improve the overall performance of the system.

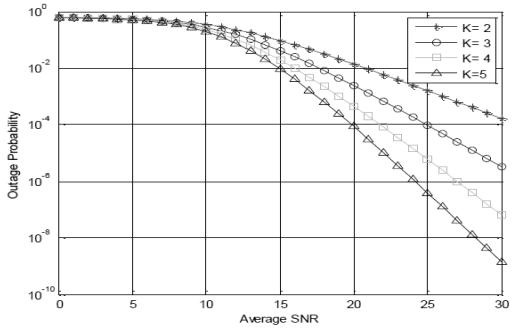


Fig. 3: Outage probability vs Average SNR for our system at R=1bps/Hz, for unbalanced link ($\overline{\gamma_1} = \overline{5\gamma_2}$) and the direct link SNR $\overline{\gamma_o}$ = 3db

It can be observed from **(Fig.4)** that the proposed scheme achieves better BER performance as the number of relays is increased. The bit error rate decreases as the number of relays increases for some fixed values of SNR because diversity gain and virtual antenna array gain are monotonically increasing function of relays (K).

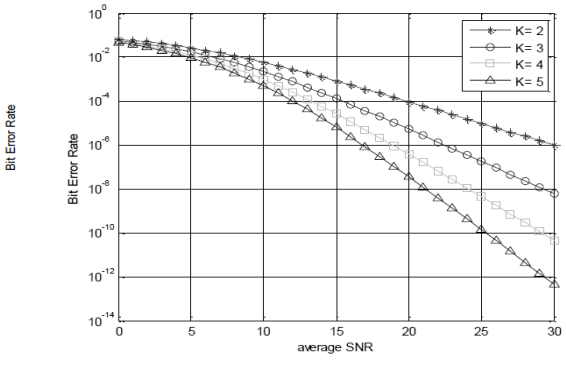


Fig. 4: BER performance against average SNR with increasing number of relays for balanced ($\overline{\gamma_1} = \overline{\gamma_2}$) and the direct link SNR γ_o = 3db

It can be observed from **(Fig. 5)** that the BER performance is improved for unbalanced link as compared to the balanced link. It shows that bit error rate decreases as the number of relays increases. By

observing **Fig.4 and 5**, it can be noticed that the BER performance achieved with unbalanced link is little more than that what we achieved in balanced link.

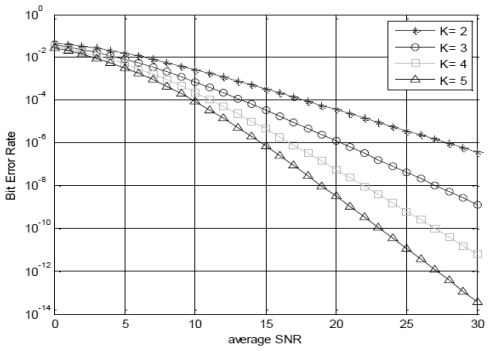


Fig. 5: BER performance against average SNR with the increasing number of relays for balanced link ($\overline{\gamma_1} = \overline{5\gamma_2}$) and the direct link SNR $\overline{\gamma_o}$ = 3db

4. CONCLUSION

In our study, we analyzed the performance of dual-hop AF multiple relay cooperative diversity network with best relay selection. The relay node that achieves the highest SNR at the destination was selected as the best relay. Our analysis indicated that full diversity order can be achieved with a single relay with fewer resources.

In best relay selection scheme, minimum signal overhead is involved at the cost of minor complexity. The overall performance of the system is dependent on the improvement in any link but better performance can be achieved if quality of both the links is improved.

REFERENCES:

Janani, M., A. Hedayat, T. E Hunter. and A. Nosratinia, (2004) "Coded Cooperation in wireless communications: space-time transmission and Iterative decoding," *IEEE Trans. Signal. Proc.*, vol. 52, 362-371.

Yijia, F. and T. John, (2007), "MIMO configuration for relays channels: Theory and Practice," *IEEE Trans. Wireless Communication.* vol. 6, no. 5, 1774-1786.

Theodore S. (2002), *Wireless communications principles and practice*, 2nd ed. New York: Prentice Hall

Salama, S. I. and H. Mohamed (2008), "Performance of Multiple-Relay Cooperative Diversity Systems with Best Relay Selection over Rayleigh Fading Channels", *EURASIP Journal on Advances in Signal Processing,* Article ID 580368, 7 doi:10.1155/2008/580368.

Aria, N. and H. Ahmadreza, (2004), "Cooperative communication in wireless networks, "*IEEE communications magazine*, vol. 42, 74-80.

Abdulhadi, S. M. Jaseemuddin, and A. Anpalagan. (2010). "A survey of distributed relay selection schemes in cooperative wireless and Ad hoc networks," *in Conference on wireless pers. Communications.*

Nabar, R. U., H. Bolcskei, and F. W. Kneubuhler, (2004), "Fading relay channels:Performance limits and space-time signal design," *IEEE J. Select. Areas Comm.,* vol. 22, 1099-1109.

Hasna, M. O. and M. S. Alouini, (2003), "End-to-end performance of transmission systems with relays over Rayleigh fading channels," *IEEE Trans. Wireless Commun.,* vol. 2, 1126-1131.

Anghel, P. A. and M. Kaveh, (2004), "Exact symbol error probability of a cooperative network in a Rayleigh-fading environment," *IEEE Trans. Wireless Commun.,* vol. 3, 1416-1421.

Hasna, M. O. and M.S. Alouini, (2003), "Outage probability of multihop transmission over Nakagami fading channels," *IEEE Communications Letters*, vol. 7, no. 5, 216–218.

Majhi, S., Y. Nasser, and J. F. Helard, (2010), "Outage performance of opportunistic amplify-and-forward relaying over asymmetric fading environment,"*IEEE Transactions on Communications,* vol. 3, 430-433.

Beres, E. and R. S. Adve, (2008), "Selection Cooperation in Multi-Source Cooperative Networks," *IEEE Transactions on Wireless Communications*, vol. 7, no. 1, 118–127.

Telatar, E. (1999). "Capacity of multi-antenna Gaussian channels," *European Trans. On Telecomm.,* vol. 10, no. 6, 585-595.