Optimal Single Relay Selection in Free Space Optical Communication for co-operative communication using Evolutionary Algorithm

[1] Vishal P. Jariwala, [2] Ravi Patel

[1] Lecturer (M.E. Student), [2] Assistant Professor,

[1] Electronics and Communication Department,

[1] Government Polytechnic, Gandhinagar, India

Abstract: Multipath fading is one of the major obstacles for next generation wireless networks which limit the bandwidth requirement of services. There are many techniques found in literature to overcome the issues of multipath fading. In free space optical communication air is the transmission medium. Due to limitations of FSO, signal does not reach to the destination with better BER. So number of relays is required between source and destination. However, co-operative communication is the major technique that has gained importance due to its ability to reduce fading. Co-operative communication is based on the relay selection technique using the channel state information at the source and relays. The main of relay based scheme is to achieve higher bandwidth efficiency. However, if the direct link between sources to destination is proper and of high quality than there is no requirement to have relay based selection technique. The work in this thesis proposes a methodology to select optimal number of relays in order to achieve better transmission efficiency. We have implemented algorithm using MATLAB and got us desired results as: PSO scheme achieves better performance among four existing schemes with improved bit error rate.

Index Terms - **FSO, Co-operative communication, Atmospheric turbulence, Bit error rate, Relay selection, optimal ordering function, Particle swarm optimization (PSO)**

I. INTRODUCTION

Bridging the so-called "last mile" in communication networks has revived keen interest in free-Space Optics (FSO), also known as fiber-free or fibreless optics, which is a technology that transports data via laser technology. It is a line-of-sight technology that currently enables optical transmission up to 2.5 Gbps of data, voice and video through the air at long distances (4km), allowing optical connectivity without deploying fiber-optic cable or securing spectrum licenses. It is moving closer to being a realistic alternative to laying fiber in access networks.

Free Space Optics, the industry term for "Cable-free Optical Communication Systems", is a line-of-sight optical technology in which voice; video and data are sent through the air (free space) on low-power light beams at speeds of megabytes or even gigabytes per second [1]. A free-space optical link consists of 2 optical transceivers accurately aligned to each other with a clear line-of-sight. Typically, the optical transceivers are mounted on building rooftops or behind windows. These transceivers consist of a laser transmitter and a detector to provide full duplex capability. It works over distances of several hundred meters to a few kilometers. Figure 1 shows 10 Gbps FSO link by MRV communication [1].

Figure 1. 10Gbps FSO Link by MRV Communication,Feb 12,2013[1]

II. SURVEY ON FSO

Optical wireless communication has emerged as a viable technology for next generation indoor and outdoor broadband wireless applications. Applications range from short-range wireless communication links providing network access to portable computers, to

last-mile links bridge ng gaps between end users and existing fiber optic communications backbones, and even laser communications in outer-space links [1]. Indoor optical wireless communication is also called wireless infrared communication, while outdoor optical wireless communication is commonly known as free space optical (FSO) communication. In applying wireless infrared communication, non-directed links, which do not require precise alignment between transmitter and receiver, are desirable. They can be categorized as either line-of-sight (LOS) or diffuse links. LOS links require an unobstructed path for reliable communication, whereas diffuse links rely on multiple optical paths from surface reflections. On the other hand, FSO communication usually involves directed LOS and point-to-point laser links from transmitter to receiver through the atmosphere. FSO communication over few kilometer distances has been demonstrated at multi-Gbps data rates.

FSO technology offers the potential of broadband communication capacity using unlicensed optical wavelengths. However, in-homogeneities in the temperature and pressure of the atmosphere lead to refractive index variations along the transmission path. These refractive index variations lead to spatial and temporal variations in optical intensity incident on a receiver, resulted in fading. In FSO communication, faded links caused by such atmospheric effects can cause performance degradation manifested by increased bit error rate (BER) and transmission delays.

FSO technology has also emerged as a key technology for the development of rapidly deployable, secure, communication and surveillance systems, which can cooperate with other technologies to provide a robust, advanced sensor communication network. However, the LOS requirement for optical links reduces flexibility in forming FSO communication networks. Compared with broadcast radio frequency (RF) networks, FSO networks do not have an obvious simple ability to distribute data and control information within the network.

The objective of the research work presented here is to answer the following questions regarding:

1) How to improve the performance of FSO links for long-range FSO communications
2) To enhance the reliability of FSO communication with efficient relay selection.
3) To reduce the Bit Error Rate (BER) in existing relay selection based FSO systems.

III. OVERVIEW OF CO-OPERATIVE COMMUNICATION

Multipath fading is one of the major obstacles for the next generation wireless networks, which require high bandwidth efficiency services. Time, frequency, and spatial diversity techniques are used to mitigate the fading phenomenon. Recently, cooperative communications for wireless networks have gained much interest due to its ability to mitigate fading in wireless networks through achieving spatial . In cooperative communication, a number of relay nodes are assigned to help a source in forwarding its information to its destination, hence forming a virtual antenna array.

Various cooperative diversity protocols were proposed and analyzed by Laneman et al. described various techniques of cooperative communication, such as decodeand- forward, amplify-and- forward, selection relaying, and incremental relayingIn [3], a distributed space-time coded (STC) cooperative scheme was proposed, where the relays decode the received symbols from the source and utilize a distributed space-time code. Su et al. derived symbol error rate (SER) for single-relay decode-and-forward and amplify-and forward cooperative techniques in [4] and [5], respectively. In [6], Sadek et al. provided SER performance analysis for the decode-and-forward multi-node schemes.

There are various protocols proposed to choose the best relay among a collection of available relays in the literature. In , the authors proposed to choose the best relay depending on its geographic position, based on the geographic random forwarding (GeRaF) protocol proposed in [14]. In GeRaF, the source broadcasts its data to a collection of nodes and the node that is closest to the destination is chosen in a distributed manner to forward the source's data to the destination. In [5], the authors considered a best-select relay scheme in which only the relay, which has received the transmitted data from the source correctly and has the highest mean signal-to-noise ratio (SNR) to the destination node, is chosen to forward the source's data. In [5], a relay-selection scheme for single relay decode-and-forward cooperative systems was proposed. In this scheme, the source decides whether to employ the relay in forwarding its information or not, depending on the instantaneous values of the source-destination and source-relay channels gain.

Co operative communication is similar to the relay channel model in some respects but differs significantly in that each wireless user is assumed to both transmit data as well as act as a cooperative agent for another user. In other words, cooperative signaling proto cols should be designed so that users can assist other users while still being able to send their own data.
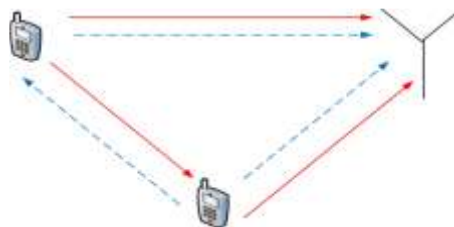

Figure 2. In cooperative communication each user is both a source and a relay

IV. RELAY SELECTION IN FSO

In wireless networks, nodes are constrained by their size, as well as power because they are powered by battery, with limited energy supply. So that it is crucial to transmit information with minimum power consumption in multi relay cooperative systems. All these works focus on the cooperation of one source with one relay or multi relay, which is known as single relay selection and multiple relay selection respectively.

In amplify & forward protocol, all relays are forced to cooperate and each relay has to use their full transmit power for cooperation. While in decode & forward protocol whether a relay would be able to decode depends on the channel quality between the transmitter and the relay. For the sack of simplicity we have considered decoding relays use their full transmit power for cooperation.

In single relay selection, only one relay can cooperate among all the relays in the network. Whereas in multiple relay selection, more than one relay can cooperate among all the relays in the network [9].
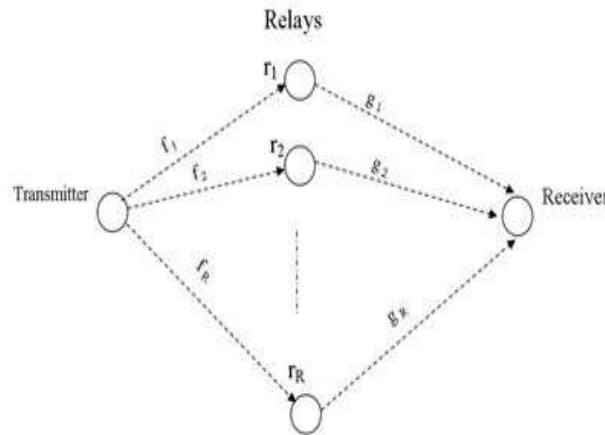
- **System Model**

Figure 2. Network model

Consider a relay network with one transmit-and-receive pair and R relays as depicted in Figure 3. Every relay has one antenna which can be used for both transmission and reception. Denote the channel from the transmitter to Relay I as fi and the channel from Relay i to the receiver as gi. Relay i knows its own channels fi and gi, and the receiver knows all channels f1. . . fR, g1, . . . , gR. Although the schemes proposed in this paper are valid for any channel statistics, for the diversity analysis, we assume that all channels are normalized i.e. Rayleigh random variables, i.e., CN (0, 1).

When only Relay i cooperates, the received SNR is

$$SNR_i = \frac{\left|f_i g_i\right|^2 PP_i}{1 + \left|f_i\right|^2 P + \left|g_i\right|^2 P_i}$$

The received SNR at relay i show, impacts of noise on the transmitted signal. Signal to noise ratio at relay i, depends on channel between transmitter to relay (fi,) channel between relay to receiver.(gi), transmission power used at transmitter (P) and transmission power used at relay (Pi).

Parametric relay selection can works as both single relay selection as well as multiple relay selection.

There are four existing relay selection schemes which are described below:'

A. Best Relay Selection

In [12], [15]–[16], the relay whose path has the maximum SNR is selected. This is obviously the optimal single RS scheme. The error rate of this scheme is first discussed in [38], which uses an approximation on the cumulative density function of the receive SNR. Then, a rigorous upper bound on the error rate is given in [12]. Both show that this scheme has the full diversity order of R.

B. Nearest Neighbor Selection

In [13], [14], nearest neighbor selection is proposed, in which the relay that is the nearest to the base station cooperates. In both papers, DF is used and node spatial positions are considered. In our AF network with perfect channel information, we use this scheme by choosing the relay with the largest P|fi|² or Pi|gi|². Note that the original scheme is slightly modified to incorporate different relay

power constraints. "The nearest relay" here is not necessarily the spatially nearest relay to the transmitter or receiver, but the relay with the strongest channel to the transmitter or receiver.

Theorem 1: The diversity order of the nearest neighbor relay selection is 1.

In this method, entire frame is divided into number of blocks of same size. This method is invariant to object motion. By computing the block motion, it is possible to enhance motion invariance.

C. Best Worse Channel Selection

For dual-hop protocols, each relay has two channels. In [14], [18], the best worse channel selection is used, in which the relay whose worse channel is the best is selected. The diversity-multiplexing trade-off of this scheme is analyzed in [18], in which the diversity analysis is based on the outage probability. To incorporate different relay power constraints, we modify the selection function to be min $\{P|fi|^2, Pi|gi|^2\}$. We work on the error rate and prove that it has full diversity.

Theorem 2: The best worse channel selection achieves the full diversity order of *R*.

D. Best Harmonic Mean Selection

In [18] and [17], the best harmonic mean selection is proposed, in which the RS function is chosen as the harmonic mean of the two channels' qualities. The one with the largest mean cooperates. Symbol error rate of this scheme is analyzed in [39]. However, the derivation is not rigorous since an upper bound on the receive SNR is used. In this paper, we first modify the selection function to be $h(f_i, g_i, P_i) = (P^{-1}|f_i|^2 + P^{-1}|g_i|^2)^{-1}$ to incorporate the different relay power constraints, then give a rigorous upper bound on the error rate.

Theorem 3: The best harmonic mean selection achieves the full diversity order of *R*.

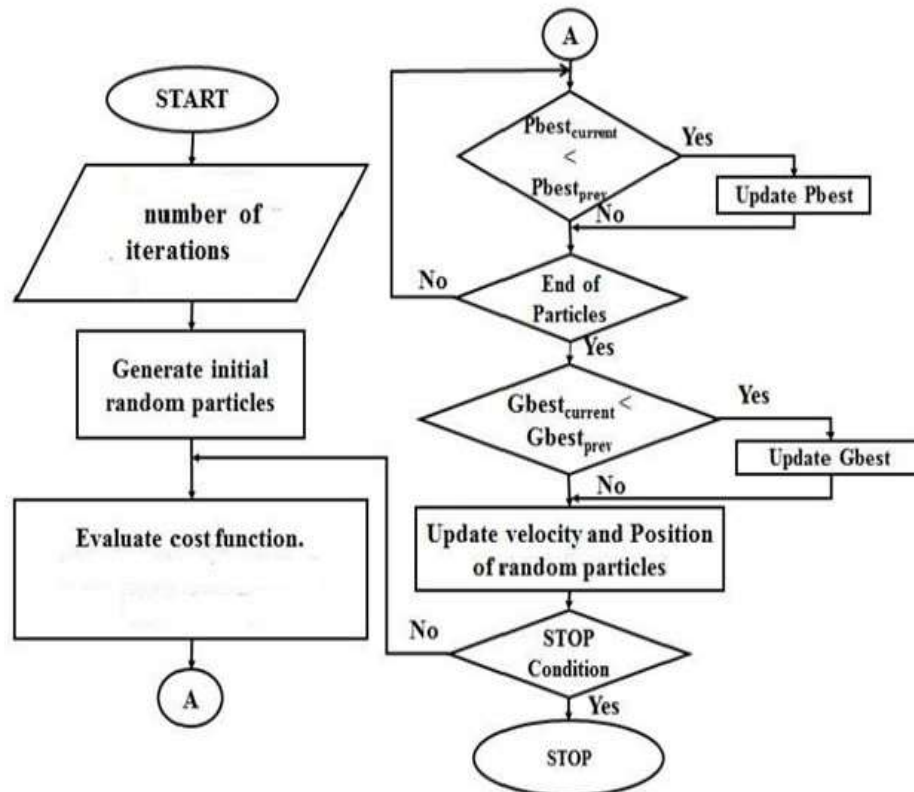## V. Particle Swarm Optimization (PSO) algorithm

Figure 3. PSO flow chart

Fig.3 shows the flowchart of PSO algorithm. This algorithm simply evaluates the fitness function and obtains its optimal solution. Here fitness function is BER, by using PSO we have evaluate the BER expression and find out the solution for minimize the bit error rate. All the particles are evaluated using the objective function and find out the best solution of that cost function For each iteration.

By using fitness function, for optimization initially we take random particles. Here the fitness function is BER. For each iteration all the random particles in the swarm are try to get the optimum value. In the next iteration each individual fitness and its achieved fitness are referred as individual best position or personal best position (P_{best}).Compare each particles P_{best} value with the current P_{best} value. If the current P_{best} value is better than P_{best} , update value as current pbest value. Until maximum iterations achieved, the algorithm repeats. The best value among the all particles is referred to as global best value (g_{best}).

VI. Simulation results and discussion

For simulation of single relay selection as well as multiple relay selection technique, we have used MATLAB as software plat form. We have considered a network with 5 relays, 1 source and 1 destination. The channels are formed among all sources to all relays and relays to destination

To check the BER performance one should consider number of symbols transmitted. Here we have considered 10000 symbols which are being transmitted from source to destination via single relay. Now the symbols are modulated and then they are transmitted at different power levels. We have considered the power levels from 0 to 15 dB with segment of 1. The BER is calculated by comparing the demodulation of received signal and reference transmitted signal. The plot of BER vs power is done. This process is repeated for all different single relay schemes and different number of relays as well.
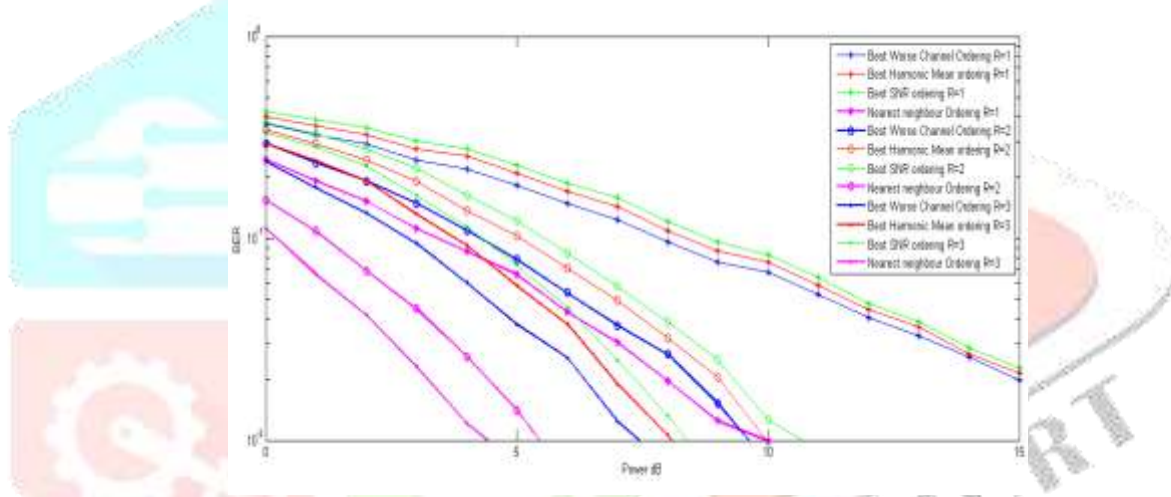

Figure 4. Comparison of four single RS schemes with relays=1,2,3

Figure 4 shows the plot of BER versus power for four single relay schemes with varying number of relays from 1 to 3. From figure, it is clear that if we consider power level 5 db, for only Best SNR ordering scheme, we get BER 0.2285, 0.1236 and 0.0716, for Relays 1, 2 and 3 respectively in the network. So we can clearly observe that as the number of relays increases in the network, performance of the n/w will be better.

Similarly, If we consider power level 5 dB and relays keeping 2 in the network, we get BER 0.0844, 0.1084,0.1252 and 0.015 respectively for Best worse channel ordering, Best harmonic mean selection, Best SNR selection, Nearest neighbor selection.

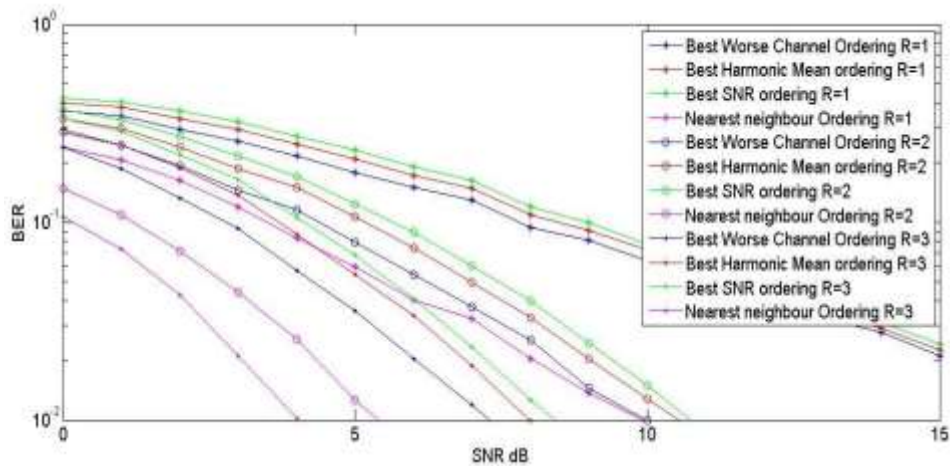It can be observed that, the performance of nearest neighbor selection is the best among all four schemes.

Figure 5. Comparison of four single RS schemes with relays=1,2,3

Figure 5 shows the plot of BER versus SNR for four single relay schemes with varying number of relays from 1 to 3. From figure, it is clear that if we consider SNR level 5 db, for only Best SNR ordering scheme, we get SNR 0.2311,0.1241 and 0.0685 ,for Relays 1,2 and 3 respectively in the network. So we can clearly observe that as the number of relays increases in the network, performance of the n/w increases.

Similarly, If we consider SNR level 5 dB and relays keeping 2 in the network, we get SNR 0.0685, 0.1064,0.1241 and 0.0127 respectively for Best worse channel ordering, Best harmonic mean selection, Best SNR selection, Nearest neighbor selection.

It can be observed that, the performance of Nearest neighbor selection is the best among all four schemes.
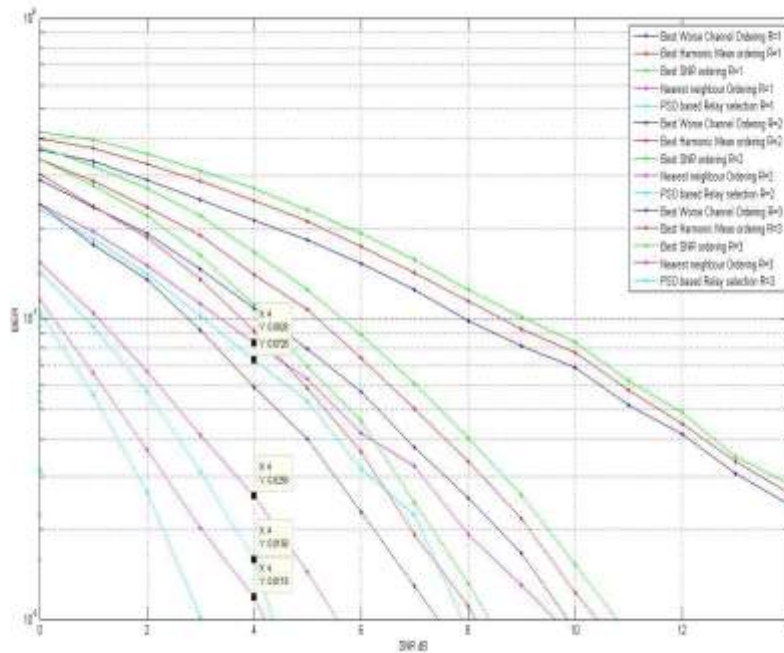
VII. Simulation results of proposed methodology

Figure 6. Comparison of PSO scheme and four single RS schemes with relays=1,2,3

Figure 6 shows the plot of BER versus SNR for four single relay schemes and PSO scheme with varying number of relays from 1 to 3.For only PSO, we get BER 0.072, 0.015 for Relays 1 and 2 respectively in the network. So we can clearly observe that by number of relays increases in the network, performance of the n/w will be better.

VI. CONCLUSION

In nearby future, FSO will become important and necessary medium of information exchange due to its advantages over fiber optics communication. Proper low cost design of transmitters is a viable and better option to prevent trenching and sunken cost of fiber optics. . The channel models for the free space optic link were studied in detail and different channel model. The simulations for all present day models were carried out using Matlab and the results presented. I introduce different relay selection methods in FSO and compare bit error rate of all four methods and PSO, We conclude that PSO gives good result and low BER with power and SNR among four existing RS schemes.

REFERENCES

[1] Mohammad Ali Khalighi," Survey on Free Space Optical Communication: A Communication Theory Perspective. IEEE Communications Surveys & Tutorials, 2013.

[2] A. A. Huurdeman, "the Worldwide History of Telecommunications", Wiley Interscience, 2003.

[3] V. W. S. Chan, "Free-space optical communications," IEEE/OSA Journal of Light wave Technology, vol. 24, no. 12, pp. 4750–4762, Dec. 2006.

[4] A. Bletsas, A. Khisti, D. P. Reed, and A. Lippman, "A simple cooperative diversity method based on network path selection," IEEE Jour. On Selected Areas in Comm., vol. 24, pp. 659-672, Mar. 2006.

[5] Ahmed S. Ibrahim nd Ahmed K. Sadek," Cooperative Communications with Relay-Selection: When to Cooperate and Whom to Cooperate With?", IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 7, NO. 7, JULY 2008

[6] Chadi Abou Rjeliy "Achievable diversity order of Decode and forward cooperative protocol for FSO links" IEE transaction VOL:61 No.9 September 2013.

[7] Chadi Abou rejeily "Performance analysis of selective relaying in cooperative FSO system" IEEE VOL:31 No.8 September/ 2013.

[8] H. Yu, I. Lee and G. L. Stuber. "Outage probability of decode-and-forward cooperative relaying systems with co-channel interference,". *IEEE Transactions on Wireless Communications*, 2012.

[9] YINDI JING AND HAMID JAFARKHANI, University of California, Irvine," Single and Multiple Relay Selection Schemes and Their Diversity Orders, *IEEE Transactions on Wireless Communication,2008.*

[10] J. N. Laneman and G. W. Wornell, " Distributed space time coded protocols for exploiting cooperative diversity in wireless network", ,". *IEEE Transactions on Info. Theory,vol.49,pp. 2415-2425,Oct 2003.*, 2012.

[11] D. S. Michalopoulos, G. K. Karagiannidis, T. A. Tsiftsis, and R. K. Mallik, "An optimized user selection method for cooperative diversity systems," in *Proc. of IEEE Globecom*, 2006.

[12] E. Koyuncu, Y. Jing, and H. Jafarkhani, "Beam forming in wireless relay networks with quantized feedback," *Submitted for publication*, 2007.

[13] A. K. Sadek, Z. Han, and K. J. R. Liu, "A distributed relay-assignment algorithm for cooperative communications in wireless networks," in *Proc. of IEEE ICC*, 2006.

[14] Y. Zhao, R. Adve, and T. J. Lim, "Improving amplify-and-forward relay networks: optimal power allocation versus selection," *IEEE Trans. On Wireless Comm.*, vol. 6, pp. 3114-3122, Aug. 2007.

[15] V. Sreng, H. Yanikomeroglu, and D. D. Falconer, "Relay selection strategies in cellular networks with peer-to-peer relaying," in *Proc. Of IEEE VTC*, 2003.

[16] Y. Zhao, R. Adve, and T. J. Lim, "Symbol error rate of selection amplify and- forward relay systems," *IEEE Comm. Letters*, vol. 10, pp. 757-759, Nov. 2006.

[17] A. Ribeiro, X. Cai, and G. B. Giannakis, "Symbol error probabilities for general cooperative links," *IEEE Trans. on Wireless Comm.*, vol. 4, pp. 1264-1273, May 2005.

[18] A. Bletsas, A. Khisti, D. P. Reed, and A. Lippman, "A simple cooperative diversity method based on network path selection," *IEEE Jour. On Selected Areas in Comm.*, vol. 24, pp. 659-672, Mar. 2006.