INTERNATIONAL JOURNAL OF ELECTRONICS AND COMMUNICATION ENGINEERING & TECHNOLOGY (IJECET)

ISSN 0976 – 6464(Print)
ISSN 0976 – 6472(Online)
Volume 5, Issue 1, January (2014), pp. 16-25
© IAEME: www.iaeme.com/ijecet.asp
Journal Impact Factor (2013): 5.8896 (Calculated by GISI)
www.jifactor.com

IJECET
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REVIEW OF RELAY SELECTION TECHNIQUES FOR COOPERATIVE COMMUNICATION SYSTEMS

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ABSTRACT

Cooperative communication aims to achieve spatial diversity gain via the cooperation of user terminals in transmission without requiring multiple transceiver antennas on the same node. It employs one or more terminals as relays in the neighborhood of the transmitter and the receiver, which collaborate in the transmission and serve as a virtual MIMO antenna array. Allowing cooperation in wireless communication engenders new problems related to resource allocation and relay selection. Optimal relay selection is vital for reaping the performance benefit of cooperative communication. It is a challenging task to share channel information in timely and distributed manner and at the same time make optimal selection of relay in a time varying radio environment. Vast variety of literature is available in which various researchers have considered parameters like received SNR, BER, PER, end to end delay, latency or geographical location to select relay.

Keywords: Cooperative Diversity, Relay Selection, Resource Allocation, Joint Optimization.

I. INTRODUCTION

Future wireless networks are expected to provide much higher data rates, energy efficiency, and reliability in a cost-effective manner. With the state-of-the-art channel coding, energy and bandwidth efficiency in point-to-point communications can be made to approach the Shannon limit. On the other hand, battery life becomes the bottleneck for wireless devices. To meet the ever-increasing demand for higher data rates and longer battery life, a promising approach to further improves the energy and bandwidth efficiency is diversity reception. Multi input multi output (MIMO) is one of the promising techniques which can offer diversity and successful in fighting against channel fading. However, it requires more than one antenna at the transmitter and/or receiver which is not feasible on small, handheld devices in ad hoc network, sensor network or up-link of cellular networks. [1-3]

Cooperation among a group of users to re-transmit each other's data can emulate a multiple transmit antennae environment to achieve spatial diversity gains. With the broadcast nature of the wireless channel, when a source transmits signals to a destination, neighboring users can also receive the signals. These neighboring users can relay the signals to the destination. As a result, diversity gain can be achieved without implementing multiple antennas or using costly RF chains. Popular cooperative schemes used by relays are (i) amplify and forward (AF) and (ii) decode and forward (DF). In AF, cooperating node simply amplifies the signal and transmits towards destination. In DF, the relay, decode and re-encode the information before sending it to destination. Cooperative protocols normally require two phases. In first phase Source broadcasts the information which can be received by relays and destination. In second phase, relays transmit it to destination.[4-5]

Due to broadcast nature of the wireless channel, at any given instant, many nodes would receive the signal transmitted by the source of the message. To include each of them in cooperation is the wastage of resources. Many replicas of the same signal re-transmitted by the relay increase traffic and hence induce interference in the channel. Researchers have proved that limited number of relays or partners participating in cooperation enhances the performance of the link. If direct channel between source and destination is satisfactory, then the cooperation of relay may not be needed. Looking at the time varying nature of the wireless channel, required number of relay is also variable. Therefore, the relay or partner selection is the crucial issue for implementing fruitful cooperative communication. Main contribution of this paper is to

1. Provide overview of various relay selection techniques
2. Highlight their benefits and challenges
3. Provide comprehensive comparison to novice researcher in this area

II. RELAY SELECTION METHODS

Relay selection is the process of selecting the ‘best’ partner or partners to achieve the goal within given constraint. Goal and constraint – both depend on the type of the wireless network. Wireless networks have variety of architectures- from cellular to sensor and infrastructure based to infrastructure less, from high profile devices to low cost low power tiny nodes. Different applications have different constraints like for sensor network, power is most important while for cellular voice communication has real time constraint and for data networks, through put is of main concern. Infrastructure based networks are centrally controlled while ad-hoc networks have distributed control. Considering variety of wireless networks, there can not be a single technique of relay selection. Vast variety of techniques can be found in recent publications. They can be put under the category as shown below:

1. Threshold based relay selection [6-10]
2. Multiple relay beamforming [11]
3. Cross layer relay selection [12]
4. Distributed relay selection [13]
5. Delay optimized relay selection[14]
6. Joint relay selection and resource optimization [15-20]
7. Joint up-down relay selection [21]

Selection of partner or relay can be done before transmitting the signal (proactive) or it can be done as and when required (reactive). The generic approach of relay selection involved three steps: Measurement, Comparison and Selection. The decision of selection can either be done by source or destination. The criteria for selection can be received SNR, end-to-end delay, bit error rate, packet error rate, frame error rate. With the relay, there are two (or more) channels involved in completing the path between the source and destination. Channel between S-R and R-D are independent. It is therefore becomes essential to consider the statistical parameter who take the effect of both the channel into account. At the same time, it is also important to optimize the resources utilized in cooperation. As a result, relay selection and resource optimization problem is undertaken simultaneously. The methods of selection and optimization jointly are employed based on power minimization, data rate (or through put) maximization, delay minimization or overhead minimization. For full duplex applications, the selection of relay can be done jointly for uplink as well as down link considering the reciprocal channel. This results in reduced overheads of election. As the wireless channel is dynamic in nature, the selection of relay has to be adaptive. The frequency of adaptation depends on the nature of the channel. Relay selection is conveniently done centrally in case of infrastructure based network, while it can be distributed in case of ad-hoc network. Centralized technique is optimum but requires more overheads while in distributed technique, fewer overheads are required for selection but it may be sub-optimal.

III. SYSTEM MODEL

The generic system model of cooperative relay network is depicted in Fig. 1. It contains one source node, one destination node, and *n* relays. The channels from the source to the relays as well as from the relays to the destination undergo independent Rayleigh fading. Thus, the channel power gains from source to relays (S-R), denoted by hi, and from relays to destination (R-D), denoted by gi, are independent, exponentially distributed random variables where $i = 1, \ldots, n$. At all nodes, the additive white Gaussian noise has a power spectral density of N_0. A node can decode data only if the received signal to noise ratio (SNR) exceeds a thresholdγ.

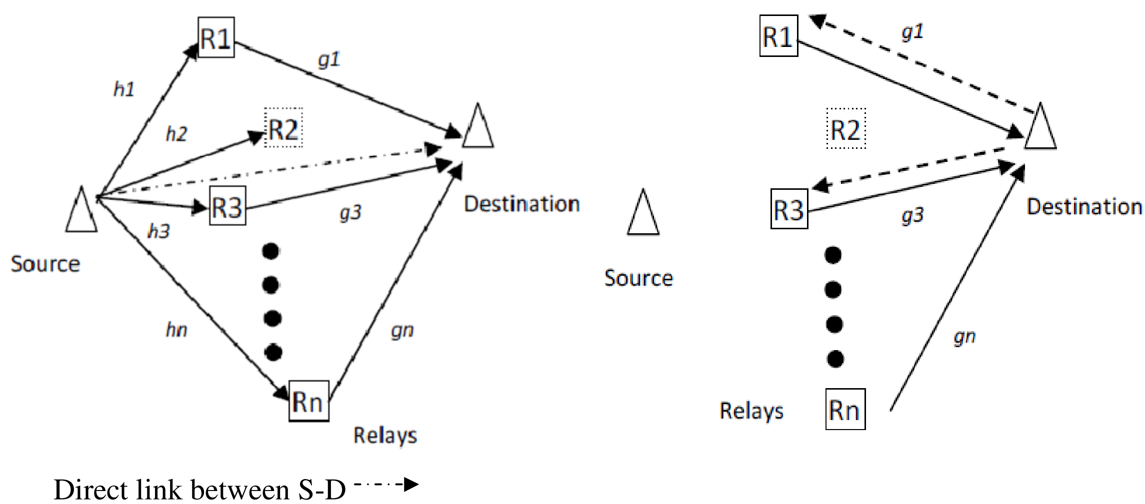

Fig. 1 General procedure of Cooperative Transmission relay selection

In phase I, source broadcasts the signal as it does not have the knowledge about the channel condition a priori. The relays whose received SNR is more than predetermined threshold is considered to be the successful relays and they participate in phase II. In phase II, successful relay sends training signal to destination from which the destination calculates the channel gain between the relay and itself. The relays having sufficient channel gain at destination are selected for the cooperation and they are informed phase III. The selected relays send the message signal towards destination. Destination combines the signals from the relays using any combining technique. If direct path is available between the source and the destination, the destination also receives the signal from source in phase I. If the received SNR between source and destination is satisfactory, destination stores the signal in buffer and later on combines it with the signal received from the selected relays.

Phase I Broadcast Source → Relays
R1, R3 , Rn decode successfully → participate in phase II
R2 cannot decode → Do not participate in phase II
Phase II Training Relays → Destination
R1, R3 , Rn send training signal to destination

Phase III Selection Destination → Relays
R1, R3 are selected as they satisfy the criteria→
participate in cooperation
Phase IV Transmission Relays → Destination
Selected relays transmit to destination

IV. RELAY SELECTION TECHNIQUES

A. Threshold based techniques

In [6-10], destination driven arbitrary multiple relay selection technique is presented in which relays are selected such that the combined SNR of direct path and relays path exceeds preset threshold as shown in Fig.2. In broadcast phase, the signal send by the source is received by the destination. It compares received SNR with threshold. If not satisfied, it selects the relay arbitrarily to send signal in next slot and combines the SNR and compare with threshold. This process continues till the received SNR exceeds the threshold. Once it happens, no more relays are selected. In this technique, channel state information is not derived by the destination by receiving the training signal but the relays are selected randomly so as to exceed the combined received SNR. Here, relay selection time depends on the channel condition as for bad channel, more relays need to get selected one after the other. In the process of decision making, the threshold is very important. In [10], optimization of decision threshold is done as a function of power and BER. This method is simplified in [9] in which the first relay with the instantaneous channel gain larger than the threshold is selected to cooperate with the source. In [7], four methods are proposed based on statistical parameters. (1) Best relRelay election in which the relay with max. SNR is selected. (2) Nearest Neighbor selection in which selection is not based on spatial position but relay with the best channel with S or D is selected (3) Best worst channel selection in which relay having best worse channel out of all S-R and R-D channels is selected (4) Best harmonic mean method in which harmonic mean of both the channels of the relay i.e. S-R and R-D is considered for selecting the relay.

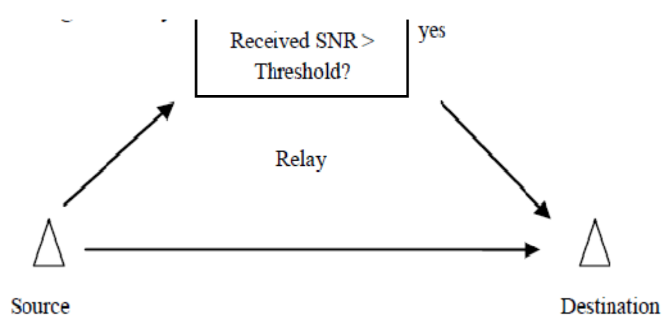

Fig.2 Threshold Based relay selection

B. Multiple Relay Beamforming

In [4], multiple relay beamforming is discussed in which destination selects relays after acquiring CSI in the absence of the direct path between source and destination. As number of selected relays increase, it further increases the energy for feedback but the energy for data transmission reduces as more relays do beamforming and diversity order increases. Energy cost increases for acquiring CSI increase with the number of total relays available. Hence, number of participating relay is also limited by energy. Here, feedback and training overheads are significant.

C. Cross layer relay selection

Timer based single relay selection using cross layer approach is discussed in [3]. This technique involves network layer in the process of selecting relay. Timer based approach is employed to avoid contention. Source send RTS message when it has data to send which is received by destination and all the relays. Destination responds by sending CTS which is also received by all relays. From RTS-CTS, all relay nodes adjust the power level necessary for cooperation based on some predetermined policy. All relays set the timer. The relay with best channel will have the shortest timer. Then source send data which is received by the destination. Destination stores it for later use. In contention stage, when timer ends, the relay send message to claim for accessing the channel. Relay send message to destination with DF protocol. Destination jointly decodes the signal.

D. Distributed relay selection

Distributed relay selection approaches are presented and compared with the centralized techniques in [5]. In distributed control mechanism, nodes have knowledge of receive SNR but not transmit SNR or no feedback mechanism is involved. There are three methods of distributed selection (1) Simple selection (2) Selection based on outage probability (3) Fixed priority selection. In simple selection, selection of partner is done randomly. As selection random, simplicity is there but some node would remain without any partner. In second method, selection of partner is done to minimize outage probability. To do so, each node hears one another's transmission and selects the partner whose transmission can be detected correctly by him with the highest received SNR. This technique leads to better performance but for that each node to overhear and decode each others' message. In fixed priority selection, each node has fixed priority list and it helps N partners starting top of that list. Compared to no-cooperation, fixed priority cooperation performs better and as number of cooperating partners increases, outage probability reduces significantly particularly in high SNR region.

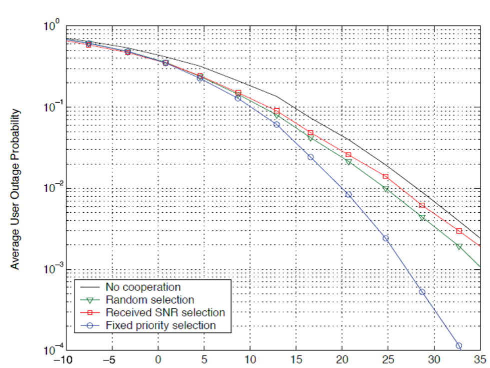

Figure: 3 Comparison of outage probability comparison of distributed & centralized techniques

Fig.3 shows that fixed priority outperforms in high SNR. Centralized control method improves the performance as distributed system chooses the optimum while centralized system chooses the best solution. Fixed priority method for selecting cooperating partner is advantageous. Centralized control improves performance but requires channel information between each node pair and the same is to be communicated to all the nodes which increase the overheads.

E. Delay optimized Relay selection

Relay selection based on minimization of total transmission time for fixed data rate systems is presented in [18]. Transmission time or end-to-end delay is important criteria for time sensitive applications. Total Time is estimated as summation of the time to decode the data for the worst case relay plus time for cooperation. If channel condition is not good, more time is needed to decode the message. After decoding, relay re-encode the message and sent. Two methods are proposed (1) Best expectation method in which the expectation of cooperation time is considered for calculating the total transmission time (2) Best-m method in which the source predetermined the number of relays depending on the channel statistic needed for cooperation for minimizing total transmission time i.e. fixed number of relays is employed. In both the methods, more than one relays are selected. Here, the advantage is overhead reduces significantly. As statistical channel distribution is considered for calculating number of relays, the solution may be sub-optimal if channel variances are large.

F. Joint relay selection and resource optimization

Relay selection process can be more fruitful if it is augmented with the resource optimization techniques. Resources in wireless networks are power, data rate (bandwidth), frequency or channel (in case of FDMA), no. of time slots (in case of TDMA), codes (in case of CDMA) or subcarriers (in case of OFDMA). For example, when the relays are selected, their powers are adjusted in such a way that the combined signal at the destination has sufficient power to just get detected. If power is not controlled at the relays, it leads to wastage of power and increased interference in the network. In [7], [8], [15] and [17] relay selection with power optimization is presented. In [9], pricing variable is introduced to optimize power and bandwidth both along with relay selection. Maximizing the minimum data rate among all the S-D pairs is considered while selecting the relay in [12].

There are M sources and N relays in the system. Let Ps and Pr be the source and relay power respectively. Pout be the outage probability and ε is the maximum tolerable outage probability. The optimization problem is formed as [8].

$$min\left(\sum_{i=1}^{M} P_{s_i} + \sum_{j=1}^{N} P_{r_i}\right)$$
$$subject\ to \begin{cases} p_{out} \leq \varepsilon \\ 0 < P_{s_i} < P_{max} \\ 0 \leq P_{r_i} < P_{max} \end{cases}$$

In case of data rate optimization, the relay with the best channel condition is selected so that it can support higher data rate transmission. For this, the optimization problem can be formulated as [9]

$$maximize \sum_{i=1}^{M} U_i\,(R_i)$$
$$subject\ to\ P \leq P_{max}$$

Where, U_m is the utility function which reflects user satisfaction and R_m is the data rate associated with relay i. The relays are selected to maximize the data rate under the constraint of the total maximum power available.

In [12], an iterative algorithm is proposed to find the optimal source-relay pairs to maximize the minimum data rate of the network, called Optimal Relay Assignment (ORA) algorithm. It is proposed for ad-hoc network where all the nodes can be source, destination or relay. The nodes which are not engaged in communication actively work as relays. Here, only one relay is assigned to each S-D pair. Direct transmission between S-D is also possible. Keys steps of this algorithm are as follows:

(i) Let C_{min} be the minimum data rate expected from the network.
(ii) In Pre-assignment phase, the data rate of all possible S-R-D pairs is calculated.
(iii) Initial assignment of relay is done randomly to all the Sources in such a way that minimum data rate for all S-R-D is more than C_{min}.
(iv) Then, a S-R pair whose data rate is minimum among all is considered for re-assignment. Let minimum achieved data rate is C_1 which is achieved by the pair S_1-R_1.
(v) From the pre-assignment table, another relay is searched for S_1 which can give higher data rate than C_1. Let that relay be R_2.
(vi) If R_2 is already not assigned to any other source, it is immediately assigned to S_1. Otherwise, another unassigned relay is searched for.
(vii) Suppose R_2 is assigned to S_2 and provides data rate more than $C_{min.}$and C_1. R_2 is required to increase the minimum data rate C_1 of source S_1. Therfore, another relay is searched for S_2 which provides data rate more than C_{min}.
(viii) Let relay R_3 be the relay which is not assigned to any source and which can provide data rate more than C_{min} and C_1 with S_2. So, S_2-R_3 and S_1-R_2 pairs are formed. Minimum data rate is more than C1 can be achieved.
(ix) These iterations are continued till all the sources get suitable relay to maximize the minimum data rate.

$$Let\ SNR_{sd} = \frac{P_s}{\sigma_{sd}^2}|h_{sd}|^2, SNR_{sr} = \frac{P_s}{\sigma_{sr}^2}|h_{sr}|^2, SNR_{rd} = \frac{P_r}{\sigma_{rd}^2}|h_{rd}|^2 \ldots\ldots..(1)$$

Where,
P_s, P_r – power transmitted by source and relay respectively
$\sigma_{sd,}^2\sigma_{sr,}^2\sigma_{rd,}^2 -$ Noise variance between S-D, S-R and R-D respectively
h_{sd}, h_{sr}, h_{rd} - path gains between S-D, S-R and R-D respectively.
In the case of Amplify & Forward protocol, relay nodes amplifies the signal and retransmits towards the destination. The data rate for AF is given as

$$C_{AF}(srd) = \frac{1}{2}W\ \log_2\left(1 + SNR_{sd} + \frac{SNR_{sr}.SNR_{rd}}{SNR_{sr} + SNR_{rd} + 1}\right) \quad \ldots\ldots\ldots.(2)$$

In case of Decode and Forward protocol, relay nodes decodes the message and re-encode before forwarding to destination. The data rate for DF is given as

$$C_{DF}(srd) = \frac{1}{2}W\ min\{\log_2(1 + SNR_{sr}), \log_2(1 + SNR_{sd} + SNR_{rd})\} \ldots\ldots\ldots\ldots(3)$$

Considering 20 Source destination pairs assisted by 30 relays. Bandwidth of each channel is 10 MHz and path loss exponent is 4. Fig.4 shows the improvement in minimum data rate with the iterations. It can be observed that minimum data rate has be en improved from the initial value of 1.75Mb/s to 4.5 Mb/s in less than 15 iterations.

In [8], Greedy & Exchange algorithm is proposed for power optimization under the constraint of outage performance. Power matrix is designed based on minimum power consumption. Then the pairs are swapped to minimize the total power consumption of the system. Power required for obtaining threshold outage probability is calculated between each S-R pairs. Power matrix is formed indicating the power required by each S-R pair.

(i) For each source, from the power matrix, a relay is found which requires the minimum power under the outage constraint. One relay is assigned once only.
(ii) Initial assignment is based on the minimum power consumption of a pair of S-R only. (Greedy Phase)
(iii) Then in exchange phase, total power consumption of all the S-R pairs are considered. The pairs of initial assignment are swap in order to reduce the overall power consumption of all the S-R pairs.

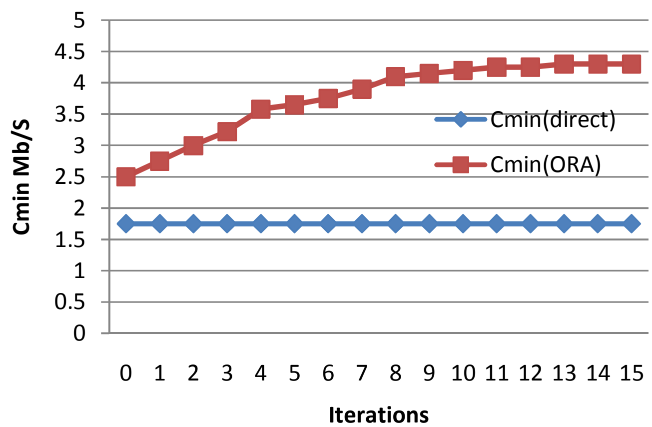

Fig.4 Minimum data rate per iteration

G. Joint Up-Down link relay selection

Relay is selected jointly for uplink and downlink to reduce overheads for selection assuming that the channel condition is same for both the direction for cellular network [10]. Traffic condition is not equal at mobile station (MS) and base station (BS). For such condition, traffic load is one of the criteria for relay selection. Traffic asymmetric factor is defined as a ratio of uplink power to total power. Energy constraints are different at MS, BS and relay. Therefore, weighted total energy consumption is considered as power constraint for MS, RS and BS. Relay is selected which minimizes the weighted energy consumption. Following is the procedure for joint relay selection:

(i) MS broadcasts a RTS1 packet to the relays and BS using a fixed transmission power P_0. Each relay hears the RTS1 packet and estimates the gain of the channel between MS and itself, Depending on the channel states, only some of the relays can be chosen as for cooperation.
(ii) The selected relays send RTS2 packets to the BS along with the channel quality indicator (CQI) using power P_0.
(iii) BS estimates the channel gain between it and relay.

(iv) BS selects the best relay and broadcasts the index of the best relay along with the transmitting power allocated to MS and the relay in UL and DL transmissions. In order to minimize the total energy consumption, the transmitting power of all transmitters in both UL and DL to the minimum required for successful transmission at an end-to-end data rate R. MS can also communicate with BS directly without the help of any relay if the channel gain of the direct link is strong enough.

(v) MS and BS communicate with each other in uplink and downlink via the selected relay. If the direct link is selected, MS and BS communicate directly with each other.

V. CONCLUSION

Proper selection of Relay or partner is very important for achieving the benefits of cooperative communication. Variety of relay selection schemes from the literature is studied and compared. Although single-relay selection is attractive due to its simplicity, it may fail to meet the QoS performance required by users due to the limited diversity gain. To enhance the service quality by increasing the cooperative diversity order, more than one relay should be favored to be involved, which leads to the multiple relay selection. Resource allocation issue can be clubbed together with relay selection results in joint relay selection and resource allocation techniques. The parameters of main concern are power, data rate, QoS, end-to-end delay and overheads. The decision of selection can either be taken centrally or in distributed manner. The centrally controlled techniques results in the "best" solution but at the cost of more processing power and significant amount of overheads. On other hand, distributed control schemes are more suitable for ad-hoc wireless network where relay selection decision is left on the individual relays, which may be sub-optimal but can be taken without much complexity and with fewer overheads.

REFERENCES

[1] A. Sendonaris, E. Erkip, and B. Aazhang, "User cooperation diversity–part I: system description," *IEEE Trans. Commun.*, vol. 51, no. 11, pp. 1927–1938, Nov. 2003.

[2] A. Sendonaris, E. Erkip, and B. Aazhang, "User cooperation diversity–part II: implementation aspects and performance analysis," *IEEE Trans. Commun.*, vol. 51, no. 11, pp. 1939–1948, Nov. 2003.

[3] J. N. Laneman, D. N. C. Tse, and G. W. Wornell, "Cooperative diversity in wireless networks: Efficient protocols and outage behavior," *IEEE Trans. Inf. Theory*, vol. 50, no. 12, pp. 3062–3080, Dec. 2004.

[4] A. Bletsas, A. Khisti, D. P. Reed, and A. Lippman, "A simple cooperative diversity method based on network path selection," *IEEE J. Sel. Areas Commun.*, vol. 24, no. 3, pp. 659–672, Mar. 2006.

[5] Y. Zhao, R. Adve, and T. J. Lim, "Improving amplify-and-forward relay networks: optimal power allocation versus selection," *IEEE Trans.Wireless Commun.*, vol. 6, no. 8, pp. 3114–3123, Aug. 2007.

[6] G. Amarasuriya, M. Ardakani, and C. Tellambura," Adaptive Multiple Relay Selection Scheme for Cooperative Wireless Networks", in *Proc. IEEE WCNC 2010*, pp. 1-6

[7] Y. Jing, H. Jafarkhani," Single and Multiple Relay Selection Schemes and Their Diversity Orders", in the proc. ICC 2008 workshop

[8] F.Atay Onat1, Y. Fan, H. Yanikomeroglu1, H. Vincent Poor, "Threshold Based Relay Selection in Cooperative Wireless Networks", in Proc. IEEE Global telecommunication Conference GLOBECOM 2008

[9] H. Niu, T. Zhang, Li Sun, "Performance Analysis of a Threshold-Based Relay Selection Algorithm in Wireless Networks", Int. Jour. of Communication & Networks, Scientific Research, Vol.2 No.2, May2010

[10] W. Pam Siriwongpairat, T. Himsoon, W. Su, K. J. Ray Liu, "Optimum Threshold-Selection Relaying for Decode-and-Forward Cooperation Protocol", in Proc. IEEE Wireless Networking and Communication Conference, WCNC2006

[11] R. Madan, N. B. Mehta, A. F. Molisch, J. Zhang, "Energy-Efficient Cooperative Relaying over Fading Channels with Simple Relay Selection", in Proc. IEEE Global telecommunication Conference GLOBECOM 2006

[12] Z. Zhou1, S. Zhou, J. Cui1, S.Cui, "Energy-Efficient Cooperative Communication Based on Power Control And Selective Relay In Wireless Sensor Networks", IEEE Trans.Wireless Commun., vol. 7, no. 8, pp. 3066 - 3078 , Aug. 2008.

[13] A. Nosratinia and T. E. Hunter, "Grouping and partner selection in cooperative wireless networks," *IEEE J. Sel. Areas Commun.*, vol. 25, no. 2, pp. 369–378, Feb. 2007.

[14] S. Nam, M. Vu, V. Tarokh, "Relay Selection Methods for Wireless Cooperative Communications", in Proc. IEEE Conf. on Information sciences & Systems CISS 2008, pp- 859 - 864

[15] M. Islam, Z. Dziong, K.Sohraby, M. Daneshmand, R.Jana, "Joint Optimal Power Allocation and Relay Selection with Spatial Diversity in Wireless Relay Networks", in proc. Mobile VCE Green Radio, Software Defined Radio - WINCOMM, 2011

[16] J.Bo SI, Z. LI, L DANG, Z. LIU, "Joint Optimization of Relay Selection and Power Allocation in Cooperative Wireless Networks", in Proc IEEE int. conf. on Communication Systems, ICCS2008, pp. 1264 – 1268

[17] Z.Qian-qian, GAO Wei-dong, PENG Mu-gen, WANG Wen-bo, "Partner selection strategies in cooperative wireless networks with optimal power distribution", Journal of China Universities of Posts and Telecommunications, Science Direct- Elsevier, Sep2008

[18] K.Vardhe, D.Reynolds, B. Woerner, "Power Allocation and Relay Selection in Cooperative Wireless Networks", in Proc IEEE Military Conf. MILCOM 2010 pp. 2108 - 2112

[19] T.Chiu-Yam Ng, Wei Yu et al," Joint Optimization of Relay Strategies and Resource Allocations in Cooperative Cellular Networks", IEEE J. Sel. Areas Commun., vol. 25, no. 2, pp. 328 - 339 , Feb 2007.

[20] S. Sharma, Yi Shi, Y. Thomas Hou, S. Kompella, "An Optimal Algorithm for Relay Node Assignment in Cooperative Ad Hoc Networks", IEEE/ACM Trans on Networking, vol. 19, no. 3, pp. 879 - 892 June 2011

[21] Wei Yang_, Lihua Li_, Gang Wu†, Haifeng Wang†, and Ying Wang, "Joint Uplink and Downlink Relay Selection in Cooperative Cellular Networks", in proc. Vehicular Technology Conf. VTC 2010.

[22] Jaafar Adhab Aldhaibani, A. Yahya , R.B. Ahmad, N. A. Al-Shareefi and M. K. Salman, "Effect of Relay Location on Two-Way Df and Af Relay in Lte-A Cellular Networks", International Journal of Electronics and Communication Engineering & Technology (IJECET), Volume 3, Issue 2, 2012, pp. 385 - 399, ISSN Print: 0976- 6464, ISSN Online: 0976 –6472.

[23] Prachi R. Shinde, Madhura Gad and Prof. S.U. Kulkarni, "Genetic Algorithm Approach into Relay Co-Ordination", International Journal of Electrical Engineering & Technology (IJEET), Volume 4, Issue 3, 2013, pp. 35 - 42, ISSN Print : 0976-6545, ISSN Online: 0976-6553.

[24] Sohrab Alam and Sindhu Hak Gupta, "Performance Analysis of Cooperative Communication Wireless Network", International Journal of Electronics and Communication Engineering & Technology (IJECET), Volume 3, Issue 2, 2012, pp. 301 - 309, ISSN Print: 0976- 6464, ISSN Online: 0976 –6472.