International Journal of Innovative Research in Advanced Engineering (IJIRAE)
Volume 1 Issue 2 (April 2014)

A Review on Partner Selection Techniques in Cooperative Communication

Sanket K. Solanki*
Electrical Department, VJTI-India
sksolanki777@yahoo.com

Pramod B. Borole
Electrical Department, VJTI-India
pbborole@vjti.org.in

Abstract-- Future generations of cellular communications requires higher data rates and a more reliable transmission link with the growth of multimedia services, while keeping satisfactory quality of service. At the same time, the mobile terminals must be simple, cheap, and smaller in size. MIMO antenna systems have been considered as an efficient approach to direct these demands by offering significant multiplexing and diversity gains over single antenna systems without increasing bandwidth and power. However, implementing multiple antennas at wireless terminal is not realistic due to size, power, cost, and weight constraints. So, Virtual MIMO known as Cooperative Diversity was introduced. In cooperative wireless networks, it is often the case that multiple sources and multiple partners cooperate to transmit their data to destination. For the cooperative systems, selecting an appropriate partner node is of prime importance. Cooperative communications can efficiently combat the severity of fading and shadowing through the assistance of partners. This paper presents the different partner selection techniques to select an appropriate partner to reduce transmission power and to improve overall performance of the wireless network.

Keywords— Cooperative communication, Partner selection techniques, Transmission topology.

I INTRODUCTION

The increasing numbers of users demanding service have encouraged intensive research in wireless communications. The problem with the cooperative communications is the unreliable medium through which the signal has to travel. To mitigate the effects of wireless channel, the idea of diversity has been deployed in many wireless systems. Diversity is a communication technique where the transmitted signal travels through various independent paths and thus the probability that all the wireless paths are in fade is made negligible. Frequency diversity, time diversity and space diversity are the three basic techniques for providing diversity to the wireless communication systems.

Multiple-input multiple-output (MIMO) systems, where the transmitters as well as receivers are equipped with multiple antennas, proved to be a breakthrough in wireless communication system which offered new degree of freedom, in spatial domain, to wireless communications. After that, MIMO became part of many modern wireless communications standards like LTE Advanced, WiMAX and Wireless LAN. However, use of MIMO in small size nodes, like used in wireless cellular networks proved to be a challenge. To address this challenge, idea of cooperative communications came into existence to implement the idea of MIMO in distributed manner. This concept says that transmitting users share each other's antennas to give a virtual MIMO concept. Though, the idea of cooperative communication was given in 2003 by Sendonaris[5], it is still considered an extensive research which is going to exploit its benefits in the next generation communication systems.

II MIMO SYSTEMS

In MIMO systems, multiple antennas are used at the transceiver. This arrangement can significantly increase data rate and reliability of the wireless link. MIMO systems use either VBLLST (Vertical Bell Laboratories Layered Space-Time) or DBLLST (Diagonal Bell Labs Layered Space-Time) algorithm. However, using multiple co-located antennas causes degradation in the system Quality of service (QoS) due to correlation between them. Also, due to size, cost, or hardware limitations, small handheld wireless devices may not be able to support multiple antennas. To overcome the above drawback, an innovative approach known as cooperative communication has been suggested to exploit MIMO's benefit in a distributed manner. Such a technique is also called a virtual MIMO, since it allows single antenna mobile terminals to reap some of the benefits of MIMO systems. This concept is illustrated in Fig-1 below.

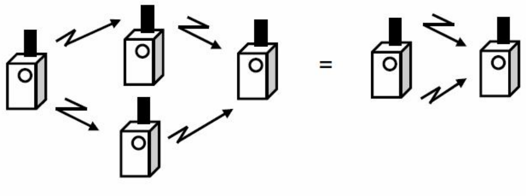


Figure 1. Illustration of MIMO and virtual MIMO systems [10]

The idea of cooperation was presented by van der Meulen in 1971, which established foundation of relay channel. Cooperative communication takes advantage of broadcast nature of the wireless medium where the neighbouring nodes overhear the source’s signals and relay the information to the destination.

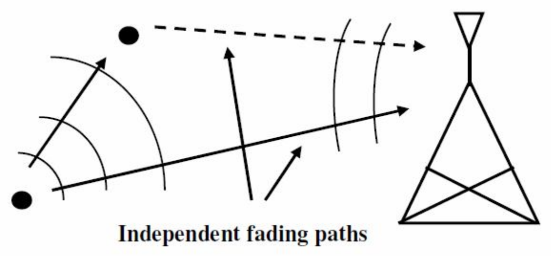


Figure 2. Cooperative Communication

Each mobile has one antenna and cannot individually generate spatial diversity. However, it may be possible for one mobile to receive the other, in which it can forward some version of "overheard" information along with its own data. Because the fading paths from two mobiles are statistically independent, this generates transmit diversity.

In Cover and El Gamal [2], three node network consisting of a source, a destination, and a relay. It was assumed that all nodes operate in the same band, so the system can be decomposed into a broadcast channel from the viewpoint of the source and a multiple access channel from the viewpoint of the destination. The relay channel model is shown in Fig 3. In this model, transmitter A sends a signal X, whose noisy, attenuated version is received by both the destination C and a relay B. The relay then transmits another signal X1 to the destination, based on what it has received.

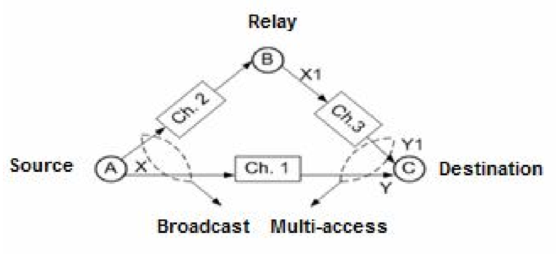


Figure 3: Relay Channel

This model can be decomposed into a broadcast channel (A transmitting, B and C receiving), and a multiple access channel (A and B transmitting, C receiving).

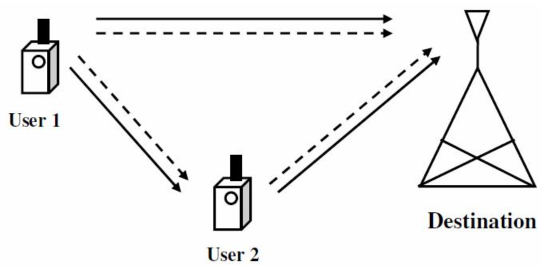


Figure 4: In Cooperative Communication each mobile is both a relay and a user

III Cooperative Communication

Cooperative communication is similar to the relay channel model to some extent 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 protocols should be designed so that users can assist there users while still being able to send their own data. This reciprocal arrangement is illustrated in Fig.4. Cooperation leads to interesting tradeoffs in code rates and transmit power. In the case of power, it may seem that more power is required because, in cooperative mode, each user is transmitting for both itself and a partner. However, the point to be made is that the gain in diversity from cooperation allows the users to reduce their transmit powers and maintain the same performance. In the face of this tradeoff, one hopes for a net reduction of transmit power, given everything else being constant. Similarly for the rate of the system. In cooperative communication, each user transmits both its own bits as well as some information for its partner, so it may appear that each user requires more bandwidth. On the other hand the spectral efficiency of each user improves because, due to cooperation diversity, the channel code rates can be increased.

ISSN: 2278-2311

Thus to summarize, in non-cooperative communication users send directly to a common destination, without repeating for one another.

The received signal can be written as :

$$\mathbf{Y_{d;r} = h_{d;r}X_2 + n_{d;r} = h_{d;r}h_{r;s}X_1 + h_{d;r}n_{r;s} + n_{d;r}} \quad (1)$$

Where $h_{d;\,r}$ is the channel from the relay to the destination nodes and $n_{r;s}$ is the noise signal added to $h_{d;r}$. In cooperative wireless, users not only transmit their own information, but also repeat other users' information during its transmission to a common destination. During the first slot, Base station receives from user1

$$\mathbf{Y_{s;\,d} = X_1h_{s;\,d} + n_{s;\,d}} \quad (2)$$

Where $Y_{s;d}$ is the signal received at destination from source, X_1 is the transmitted signal, $h_{s;d}$ is the channel gain and $n_{s;d}$ is the AWGN noise. In the next time slot, it receives the relayed version of the same information from its partner, user 2 as

$$\mathbf{Y_{r;\,d} = X_1h_{s;\,d} + n_{s;\,d}} \quad (3)$$

Here $Y_{r;d}$ is the signal received at destination from relay or cooperating user, X_1 is the transmitted signal of user 1, relayed be its partner, $h_{r;d}$ is the channel gain, and $n_{r;d}$ is the AWGN noise. These two copies of the same signal received at BS are combined and used by the receiver for decision making or decoding purpose.

IV Cooperative Transmission Protocols

A. Amplify and Forward Method

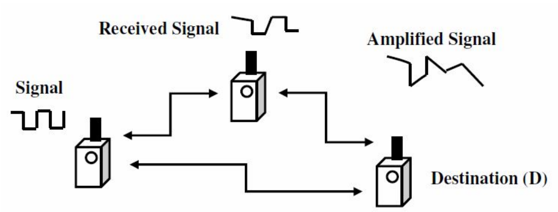


Figure 5: Amplify and Forward method [4].

Laneman and Wornell first proposed amplify-and-forward as a cooperative signaling scheme in [4]. Amplify-and-forward is conceptually the most simple of the cooperative signaling method. In this method, each user receives a noisy version of the signal transmitted by its partner; the user then amplifies and retransmits this noisy signal (see Fig 5).The destination will combine the information sent by the user and partner and will make a final decision on the transmitted symbol. Although the noise of the partner is amplified , the destination still receives two independently-faded versions of the signal and is thus able to make better decisions for the transmitted symbols. A potential challenge in this scheme is that sampling, amplifying, and retransmitting analog values may be technologically non-trivial.

Nevertheless, amplify-and-forward is a simple method that lends itself to analysis, and therefore has been very useful in furthering the understanding of cooperative communication system.

B. Decode and Forward Method

The first work proposing a detect-and-forward protocol for user cooperation was by Sendonaris, Erkip, and Aazhang [5]. Nowadays a wireless transmission is very seldom analogue and the partner has enough computing power, so Detect and Forward is most often the preferred method to process the data in the partner. The received signal is first decoded and then re-encoded. So there is no amplified noise in the sent signal, as is the case using Amplify and Forward protocol. There are two main implementations of such a system. The partner can decode the original message completely. This requires a lot of computing time, but has numerous advantages. If the source message contains an error correcting code, received bit errors might be corrected at the partner station. Or if there is no such code implemented a checksum allows the partner to detect if the received signal contains errors. Depending on the implementation an erroneous message might not be sent to the destination. But it is not always possible to fully decode the source message. The additional delay caused to fully decode and process the message is not acceptable, the partner might not have enough computing capacity or the source message could be coded to protect sensitive data. In such a case, the incoming signal is just decoded and re-encoded symbol by symbol. So neither an error correction can be performed nor a checksum calculated.

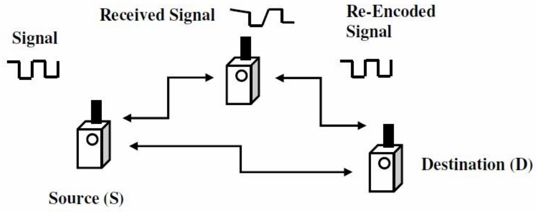


Figure 6: Decode and Forward Method [5].

C. Compress and Forward Method

The main difference between compress-and forward and decode/amplify-and-forward is that in the later the partner transmits a copy of the received message, while in compress and forward the relay transmits a quantized and compressed version of the received message. Therefore, the destination performs the reception function by combining the received message from both source node and its compressed version from the partner node. The quantization and compression process at partner node is a process of source encoding, i.e., representation of each received message as a sequence of symbols. Let us assume that these symbols are binary digits (bits). At the destination, an estimate of the compressed message is obtained by decoding the received sequence of bits. This decoding operation involves mapping of received bits into a set of values that estimate the transmitted message. This mapping process normally involves the introduction of distortion, which can be considered as a form of attenuation and noise.

D. Coded Cooperation Method

Coded cooperation differs from the previous schemes such that the cooperation is implemented at the level of the channel coding subsystem. We know in both amplify and forward and decode-and-forward schemes, the partner repeats the bits sent by the source. In coded cooperation incremental redundancy at relay, which when combined at the receiver with the codeword sent by the source, results in a codeword with larger redundancy.

V APPLICATIONS

- Cooperative sensing for cognitive radio
- Wireless Ad-hoc Network
- Wireless Sensor Network
- Vehicle-to-Vehicle Communion

VI Partner Selection Techniques

In cooperative communication, to choose the partner or relay or set of them, is the challenging task. The proper selection of the relay can effectively improve the overall performance of the network in terms of higher data rate/through put, lower power consumption and better bit error rate performance. The relay is based on the performance indices like Channel state information (CSI), Signal to noise ratio (SNR), Packet error rate (PER) etc. The relay is not to be selected by only considering the source to destination performance but it must be done by keeping the overall system performance in view. The relay selection can be classified as follows.

- **Group selection-** In this method, relay selection occurs before transmission. The purpose of selection is to achieve certain pre-defined performance level
- **Proactive selection-** In this method relay selection is performed by the source, the destination, or the relay itself during the transmission time
- **On-demand selection-** Here relay selection is performed when needed i.e. when direct channel conditions decrease below a pre-defined threshold.

Depending on the relation between the network entities, relay selection mechanisms can be divided into two categories:

- Opportunistic Partner Selection
- Cooperative Partner Selection

The basic opportunistic relay selection scheme is based on local measurements. They can be further classified as

- Measurement-based partner selection
- Performance-based partner selection
- Threshold-based partner selection

All these three approaches are opportunistic and follow a proactive selection approach.

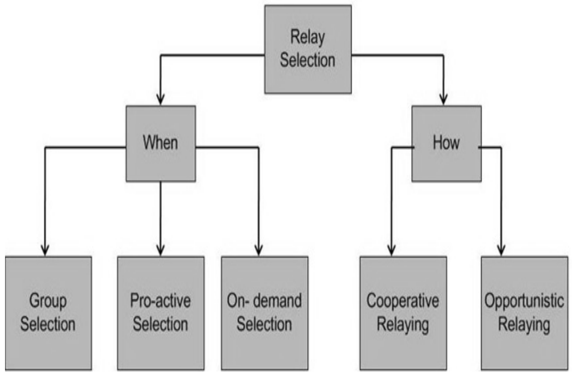


Figure 7: Partner selection

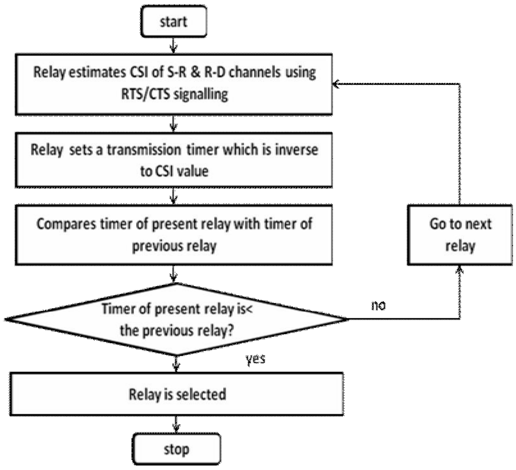
The on-demand selection category (e.g. Adaptive relay selection) follows a different approach, in which the relay selection procedure is only triggered if needed.

Contrary to opportunistic relay selection, cooperative relay selection procedures require the exchange of information among the involved communication nodes. In this case there are two categories:

- Table-based relay selection that leads to the selection of a controlled number of relays (one or two) based on information kept by the source
- Contention-based relay selection that leads to the selection of a set of a variable number of relays.

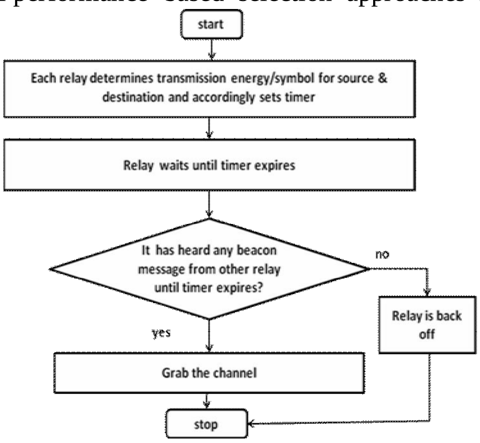
[1] Measurement-based Partner Selection

Measurement-based relay selection approaches are characterized by requiring no topology information, being based only on local measurements of instantaneous channel conditions. This technique is proposed by H. Shan [6]. Measurement-based approaches are able to select the best relay among N devices, but for this they may require 2N channel state estimations.



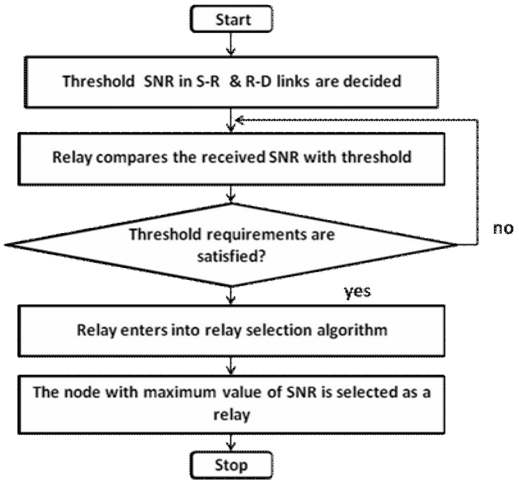
[2] Performance-based Partner Selection

Performance-based selection approaches rely on performance criteria like delay and energy efficiency to select the most suitable relay [7]. The operation of performance- based selection approaches is as follows:



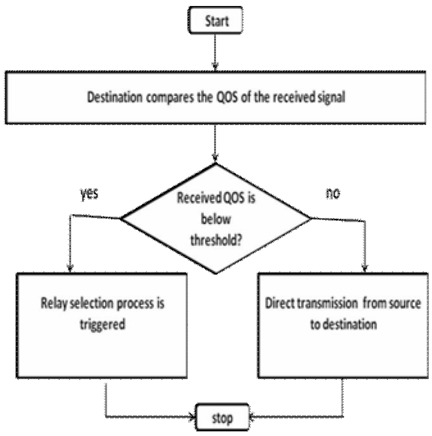
[3] Threshold-based Partner Selection

Threshold-based approaches rely on a certain threshold to reduce the number of competing relays, and thus reducing the overhead of channel estimations.



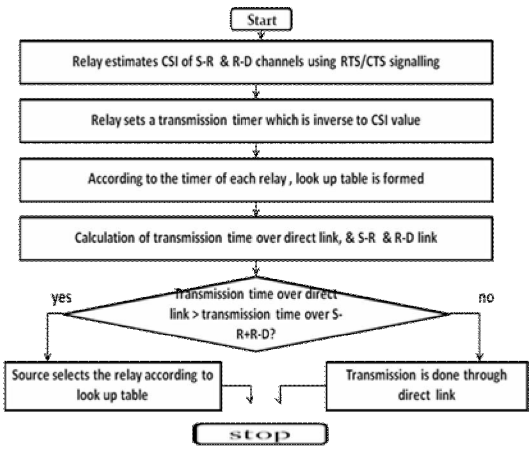
[4] Adaptive Partner Selection

Due to variations on channel conditions the PER of the link from source to destination may decrease in a way that relaying over a helping node is not needed. Adaptive relay selection approaches propose to perform relay selection only if relaying is needed with high probability. An example of adaptive relay selection is Adam et al. [9].



[5] Table-based Partner Selection

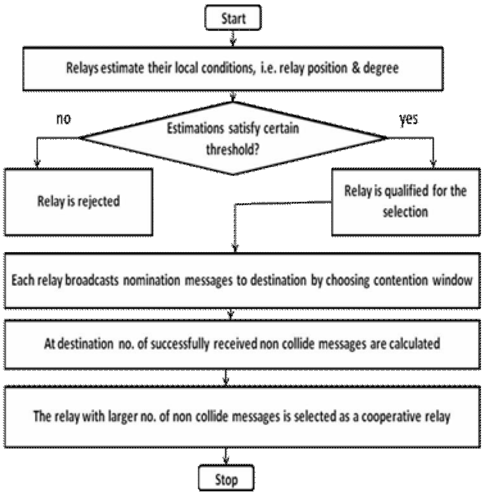
Table-based approaches [9] follow a cooperative relay selection process aiming to decrease the impact of relay selection on transmission time



Here sources keep CSI information about the links between themselves and potential relays as well as about the links from potential relays and each potential destination. The CSI information is gathered using RTS/CTS frames as well as information collected from overhead transmissions. Relays are selected by the source by looking up in a table. A node may be selected as relay if the transmission time over the direct link to a destination is higher than the sum of the transmission time over the source-relay and relay-destination links.

[6] Contention-based Partner Selection

Contention-based selection follows a cooperative approach making use of contention windows to increase the probability of selecting the best relay, aiming to achieve a good resource allocation.



VII CONCLUSION

This study provides the different types of partner selection techniques in Cooperative communication. The proper selection of the partner can effectively improve the overall performance of the network in terms of higher data rate/through put, lower power consumption and better bit error rate performance.

References

[1] Juhi Garg, Priyanka Mehta and Kapil Gupta, "A Review on Cooperative Communication Protocols in Wireless World",(IJWMN) Vol. 5, No. 2, April 2013
[2] T. M. Cover and A.A.E. Gamal. “Capacity theorems for the relay channel” IEEE Trans. Info. Theory, vol. 25, no. 5, September 1979.
[3] K.-S. Hwang and Y.-C. Ko, “An Efficient Relay Selection Algorithm for Cooperative Networks,” in Proc. of IEEE VTC.
[4] J. N. Laneman. “Cooperative diversity in wireless networks: Algorithms and architectures.” Ph.D.Dissertation, Massachusetts Institute of Technology, August 2002.
[5] A. Sendonaris, E. Erkip, and B. Aazhang, “User cooperation diversity-part I: system description,” IEEE Trans. on Communication, vol. 51, pp. 1927-1938, Nov. 2003.
[6] H. Shan, W. Z. P. Wang, and Z. Wang, “Cross-layer Cooperative Triple Busy Tone Multiple Access for Wireless Networks,” in Proc. of IEEE Globecom, New Orleans, USA, Dec. 2008.
[7] Z. Zhou, S. Zhou, J. Cui, and S. Cui, “Energy-Efficient Cooperative Communications based on Power Control and Selective Relay in Wireless Sensor Networks,” IEEE Journal on Wireless Communications, vol. 7, no. 8, pp. 3066-3078, Aug.2008.
[8] W. P. Siriwongpairat, T. Himsoon, W. Su and K. J. R. Liu, “Optimum Threshold-Selection Relaying for Decode-and-Forward Cooperation Protocol,” in Proc. of IEEE WCNC, Las Vegas, USA, Apr. 2006.
[9] H. Adam, C. Bettstetter, and S. M. Senouci, “Adaptive Relay Selection in Co- operative Wireless Networks,” in Proc. of IEEE PIMRC, Cannes, France, Sep.2008.
[10] K. Tan, Z. Wan, H. Zhu, and J. Andrian, “CODE: Cooperative Medium Access for Multirate Wireless Ad Hoc Network,” in Proc. IEEE of SECON, California, USA, Jun. 2007.
[11] Himanshu Katiyar, Ashutosh Rastogi and Rupali Agarwal, “Cooperative Communication: A Review,” IETE 2011