Partner Selection in Cooperative Communication

Major Project Report

Submitted in partial fulfillment of the requirements

for the degree of

Master of Technology

In

Electronics & Communication Engineering

(Communication Engineering)

By

Vyoma J. Mehta

(10MECC15)

Department of Electronics & Communication Engineering

Institute of Technology

Nirma University

Ahmedabad-382 481

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Under the guidance of

Prof. Manisha Upadhyay

Department of Electronics & Communication Engineering

Institute of Technology

Nirma University

Ahmedabad-382 481

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Declaration

This is to certify that

1. The thesis comprises of my orginal work towards the degree of Master of Technology in Communication Engineering at Nirma University and has not been submitted elsewhere for a degree.

2. Due acknowledgement has been made in the text to all other material used.

Vyoma J. Mehta

Certificate

This is to certify that the Major Project entitled **"Partner selection in cooperative Communication"** submitted by **Vyoma J. Mehta (10MECC15)**, towards the partial fulfilment of the requirements for the degree of Master of Technology in Communication Engineering of Nirma University, Ahmedabad is the record of work carried out by him under our supervision and guidance. In our opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of our knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

Date:

Place: Ahmedabad

Guide

Prof. Manisha Upadhyay
(Associate Professor, EC)

Program Coordinator

Dr. D. K. Kothari
(Professor, EC)

HOD

Prof. A.S.Ranade
(Professor, EC)

Director

Dr. K Kotecha
(Director, IT, NU)

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- Vyoma J. Mehta
10MECC15

Abstract

With the revolution in technology, most of the communication systems are going to be wireless. But wireless communication performance is badly affected by channel fading. One of the possible solutions is MIMO, but it is not always possible to provide more than one antenna, due to size constraints. So virtual MIMO, known as cooperative diversity was introduced, to provide diversity. This thesis explores networks with source, destination and relay, different transmission protocols and relay selection techniques. In cooperative wireless networks, it is often the case that multiple relays cooperate with multiple sources, to transmit their data to destination. For the cooperative systems, selecting an appropriate relay node is of prime importance. Various relaying algorithms are used to select appropriate relay. In this thesis, the algorithm, namely greedy and exchange algorithm(GAEA) and parametric relay selection is used for relay selection. GAEA aims to minimize the total transmission power in the multi source and multi relay wireless networks in which one source has only one partner to help for information transmission. Later on, based on the analysis and the mechanism used in GAEA, an alternative version of GAEA is provided, that enhances the algorithm for more optimized result.Simulation results shows that modified greedy and exchange algorithm can save the transmission power. Parametric relay selection aims to minimize the bit error rate and outage probability and to maximize the data rate, in single source and multi relay wireless networks by using single relay selection and multiple relay selection. Simulation results shows that single relay selection schemes perform much better than the multiple relay selection scheme.

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List of Abbreviation

AF	Amplify and Forward
BER	Bit Error Rate
CSI	Channel State Information
DF	Decode and Forward
DF-DT	Decode and Forward Direct Transmission
MIMO	Multiple Input Multiple Output
PER	Packet Error Rate
P_{out}	Probability of outage
RTS	Request to Send
CTS	Clear to Send
GAEA	Greedy and Exchange Algorithm

Chapter 1

Introduction

1.1 Motivation

Now a days wireless communications have gained much popularity in recent years due to its ability to provide unbound connectivity and mobile access. But reliable and high data-rate communication over the wireless channel has been unsuccessful due to multipath fading, shadowing, and path loss effects. One of the possible solution is to develop effective transmit and receive diversity techniques to exploit diversity in different channel dimensions, such as time, frequency, and space, and achieve the so-called diversity gains. Multiple-input multiple-output (MIMO) systems have made it desirable to embed multiple antennas on modern wireless transceivers, in order to achieve spatial diversity gains. However, as the size and cost of wireless devices are limited for many applications, e.g., in sensor networks or for cellular phones, placing multiple antennas on a single terminal may not be practical.

In this case, cooperating with other nodes in the network to form a distributed antenna system becomes a desirable and promising alternative.This is achieved by the so-called cooperative communications.

1.2 Wireless Communication

Now a days in wireless communication systems throughput over wireless channel and the reliability of wireless communication has been increased. As a result, uses of wireless systems have increased. Although wired communication provides more stability, better performance, and higher reliability, it needs certain bounded environment. On the other way wireless communication provides portability, mobility, and accessibility, so that there are numbers of challenges such as: a need for high data rates, quality of services, mobility, portability, connectivity in wireless networks, interferences from other users, privacy/security.

1.3 Fading

In wireless system, due to the change in transmission medium or paths, signal can travel from transmitter to receiver through multiple paths which is known as multipath Propagation, which causes time variation of received signal power. In wireless communication due to the multipath propagation fluctuation occurs in signal's amplitude, phase and angle of arrival.

In multipath fading, there are basic three propagation mechanisms as shown in Figure 1.1:

- **Reflection:** It occurs when a propagating electromagnetic signal encounters a smooth surface that is large relative to the signal wavelength.
- **Diffraction:** It occurs at the edge of a dense body that is large compared to the signal Wavelength.
- **Scattering:** It occurs when the propagating radio wave encounter a surface with dimensions on the order of the signal wavelength or less, causing the incoming signal to spread out (scatter) into several weaker outgoings in all directions.

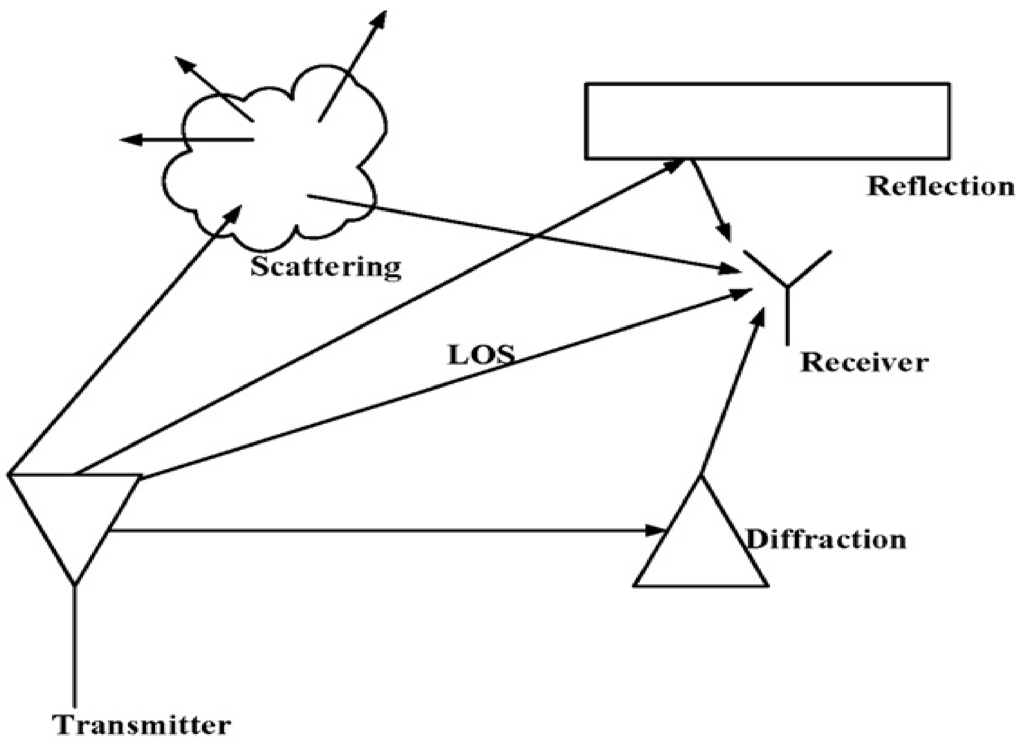

Figure 1.1: An example of different paths in a wireless channel

1.3.1 Types of Fading

- **Slow Fading:** It represents the average signal power attenuation or path loss due to moving over large or long distance area.

- **Fast Fading:** It refers to the rapid changes in signal power and phase that occur due to small movement over distance of about half wavelength.

- **Selective Fading**: A channel experience selective fading when the received multipath component of a symbol extends beyond the symbol time duration.

- **Flat Fading:** flat or nonselective fading occurs when all received multipath component of a symbol arrive within the symbol time duration.

1.4 Diversity

In wireless communication, channels experience fading events, multiple channels can be used between transmitter and receiver to compensate these error effects. By using diversity techniques the errors cannot be eliminated completely but can be reduced to some extent by combining several copies of the same message received over different multiple channels. The independent fading channels are obtained by antenna, site, time, frequency and polarization.

- **Antenna Diversity:** Multiple array of antennas are used to transmit different copies of the signal and then combine them at receiver to construct the transmitted message.The antennas are located in the same place (e. g. base station tower) and their spacing is of a few wavelengths.

- **Site diversity:** In site diversity the receiving antennas are located in different places so as not only the multipath fading is independent but also the shadowing and path loss will be independent to some extent.

- **Time Diversity:** In time diversity the same message is transmitted many times at different instances of time. For effective time diversity, the time difference should be more than coherent time of the channel.

- **Frequency Diversity:** In frequency diversity more than one copy of the message is transmitted by spreading the signal out over large bandwidth or carried on multiple frequency carriers. To achieve effective diversity using frequency diversity, the carrier frequencies should be separated by more than bandwidth coherence.

- **Polarization Diversity:** Obstacles scatter waves differently depending on polarization.Polarization diversity use a set of cross polarized receiving antennas so that the received waves do not cancel each other.

1.5 Problem Statement

The objective of this thesis is to study and compare various relay selection techniques in cooperative communication. The relay selection is the major challenge in cooperative communication, because proper selection of relay can effectively change overall network performance. The simulations will be carried out in MATLAB and the outcomes will be compared.

1.6 Thesis Organization

The rest of the thesis are organized as follows organized as follows:

Chapter 2: This chapter deals with introduction to cooperative communication and transmission protocols and advantages and limitation of cooperative communication.

Chapter 3: This chapter deals with introduction to different Relay selection Techniques.

Chapter 4: This chapter deals with introduction to relay selection algorithms like Greedy And Exchange Algorithm(GAEA) and parametric relay selection.

Chapter 5: This chapter deals with discussion of simulation results of Greedy And Exchange Algorithm(GAEA) and parametric relay selection.

Chapter 6: This chapter comments on the results of the simulations and concludes with the further work on this project.

Chapter 2

Cooperative Communication

2.1 Introduction

Wireless communication systems are expected to provide a variety of services including voice, data and video. The rapidly growing demand for these services needs high data rate wireless communication systems with reliability and high user capacity. Recently, it has been shown that reliability and achievable data rate of wireless communication systems increases by employing multiple transmit and receive antennas. Transmit diversity is a powerful technique for combating multipath fading in wireless communications. However, employing multiple antennas in a mobile terminal to achieve the transmit diversity is not feasible due to the limited size of the mobile unit. In order to overcome this problem, a new mode of transmit diversity called cooperative diversity based on user cooperation, was proposed. By user cooperation, it is meant that the sender transmits information to the destination and copies to other users, called partners, for relaying to the destination. The antennas of the sender and the partners together form a multiple antenna situation.

Modern communication systems are an important part of our day to day life. Especially, wireless communication systems such as mobile phone, wireless local area network (WLAN),Bluetooth, etc., provide the freedom for users to roam and to communicate from anywhere at any time. The next generation broadband wireless communication systems are expected to provide wireless multimedia services such as high speed Internet access, multimedia message services (MMS) and mobile computing. In this case, the wireless communication system designers face a number of challenges which include the limited availability of the radio frequency spectrum and a complex time-varying wireless channel environment. In addition, meeting the increasing demand for high data rates, better quality of service (QoS), fewer dropped calls, longer battery life and higher network user capacity paves the way for innovative techniques that improve spectral efficiency and link reliability. A signal transmitted through a wireless channel arrives at the destination along multiple paths. These paths arise from scattering, reflection and diffraction of the transmitted energy by the objects in the environment. The signals arriving along different paths are attenuated and interfere with each other. Time varying multipath signals give rise to effects in different dimensions such as time (delay spread), frequency (Doppler spread) and space (angle spread). Depending on the transmitted signal bandwidth, the fading channel can be viewed as frequency selective, time selective and space selective. The presence of channel impairments degrades the signal-to-noise-ratio (SNR) at the receiver. Sophisticated transmission/reception methods are needed to mitigate channel impairments.

A popular technique successful in the adversing effects of channel fading is diversity. Diversity can be implemented in the temporal dimension through the use of channel coding and an interleaver, the frequency dimension through frequency hopping, or in the spatial dimension through multiple antennas. In all cases, diversity allows a user to average the fades such that a user sees a channel with lower variance. Traditionally, spatial diversity is implemented with multiple antennas at the transmitter and receiver. Spatial diversity, however, can also be implemented in a distributed fashion by employing other terminals in the system as virtual antennas. This technique, referred to as relaying or cooperative diversity, requires a terminal to act as a relay for a source terminal in its transmission to the destination.

We use the term multihop for a scenario where the destination does not process the information arriving directly from the source, i.e., the information flow is strictly between the source and relay and relay and destination.

Cooperative communication allows single antenna mobiles to share their antennas and to produce virtual multiple-antenna system. Figure 2.1 shows two mobile agents communicating with the same destination.

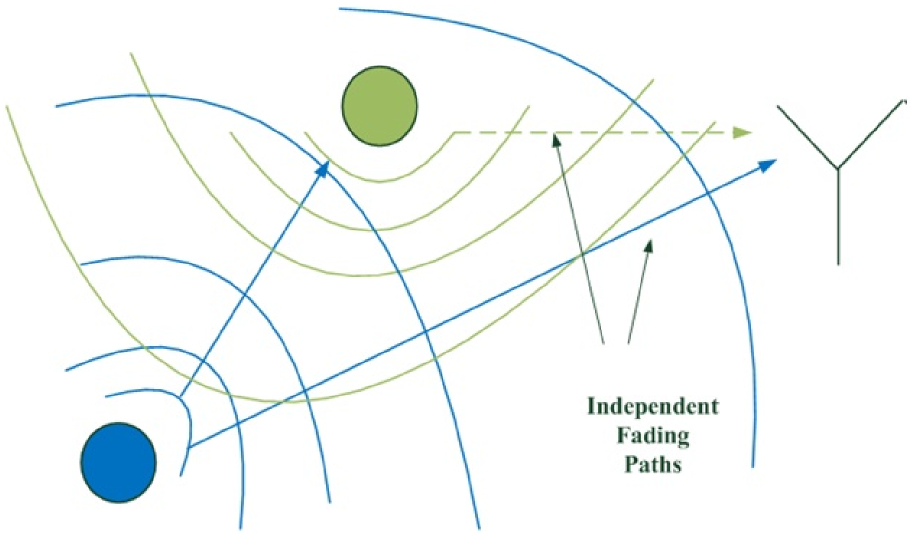

Figure 2.1: Cooperative communication

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.

2.2 Background

In Cover and El Gamal[21], 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 Figure 2.2. 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. 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)

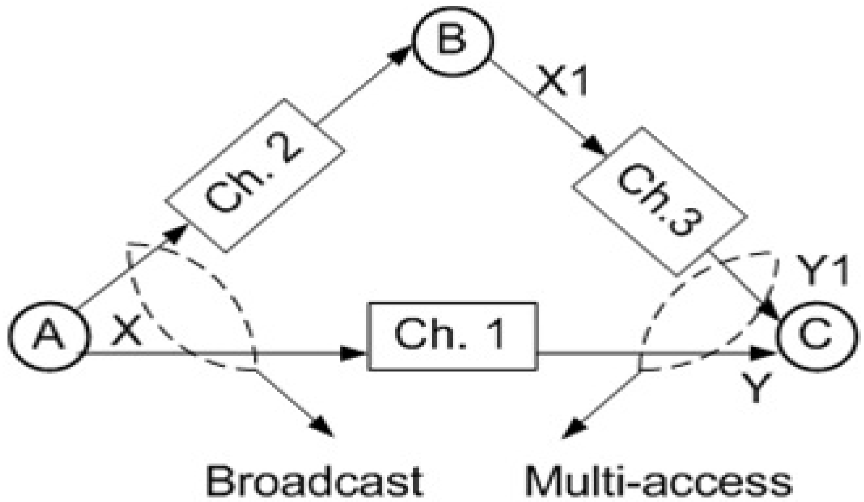

Figure 2.2: Relay Channel

Cover and El Gamal calculated the information theoretic capacity of this channel and found that it is bounded by the minimum of the rates of transmission of the Constituent broadcast and multiple access channels. In many instances, the overall capacity is better than the individual capacity between A and C. However, in many respects the cooperative communication is different from the relay channel. First, recent developments are motivated by the concept of diversity in a fading channel, while Cover and El Gamal mostly analyze capacity in an additive white Gaussian noise (AWGN) channel. Second, in the relay channel, the relay's sole purpose is to help the main channel, whereas in cooperation the total system resources are fixed, and users act both as information sources as well as relays.

2.3 Cooperative Communication

Cooperative communication is similar to the relay channel model to some extenet 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 other users while still being able to send their own data. This reciprocal arrangement is illustrated in Figure 2.3.

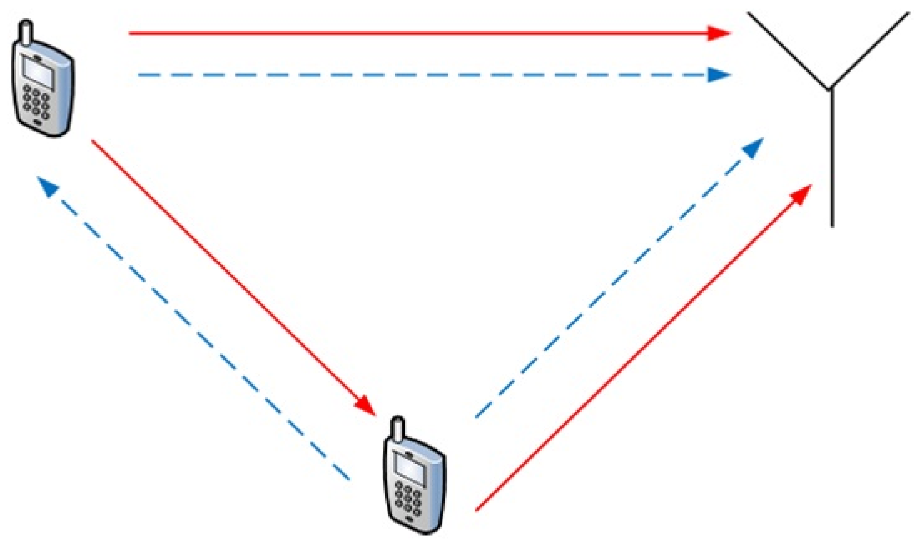

Figure 2.3: Relay Channel in cooperative communication

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 tradeff, 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 Thus, in non-cooperative communication users send directly to a common destination, without repeating for one another. The received signal can be written as [30]:

$$Y_{s,d} = X1h_{s,d} + n_{s,d} \tag{2.1}$$

Where $Y_{s,d}$ is the signal received at destination from source, X1 is the transmitted signal, $h_{s,d}$ is the channel gain and $n_{s,d}$ is the AWGN noise. In cooperative communication, 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

$$Y_{s,d} = X1h_{s,d} + n_{s,d} \tag{2.2}$$

Where $Y_{s,d}$ is the signal received at destination from source, X1 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

$$Y_{r,d} = X1h_{r,d} + n_{r,d} \tag{2.3}$$

Here $Y_{r,d}$ is the signal received at destination from relay or cooperating user, X1 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 Base Station are combined and used by the receiver for decision making or decoding purpose.

2.4 Cooperative Transmission Protocols

In cooperative communications, independent paths between the user and the base station are generated via the relay channel. The relay channel can be thought of as an auxiliary channel to the direct channel between the source and destination. A key aspect of the cooperative communication process is the processing of the signal received from the source node done by the relay. These different processing schemes result in different cooperative communications protocols. The processing at the relay differs according to the employed protocol. Cooperative communications protocols can be generally categorized into amplify and forward and decode and forward relaying schemes.

In the amplify and forward (AF) relaying protocol, the relay simply scales the received version and transmits an amplified version of it to the destination. Another possibility of processing at the relay node is for the relay to decode the received signal, re-encode it and then retransmit it to the receiver. This kind of relaying is termed as a decode-and-forward (DF) relaying protocol.

A typical cooperation strategy can be modeled with two orthogonal phases, to avoid interference between the two phases:

In phase 1, a source sends information to its destination, and the information is also received by the relay at the same time. In phase 2, the relay can help the source by forwarding or retransmitting the information to the destination.

2.4.1 Amplify and Forward Method

Laneman and Wornell first proposed amplify-and-forward as a cooperative signaling scheme in [15]: Amplify-and-forward is conceptually the most simple of the cooperative signaling methods. 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 Figure 2.4). 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 systems.

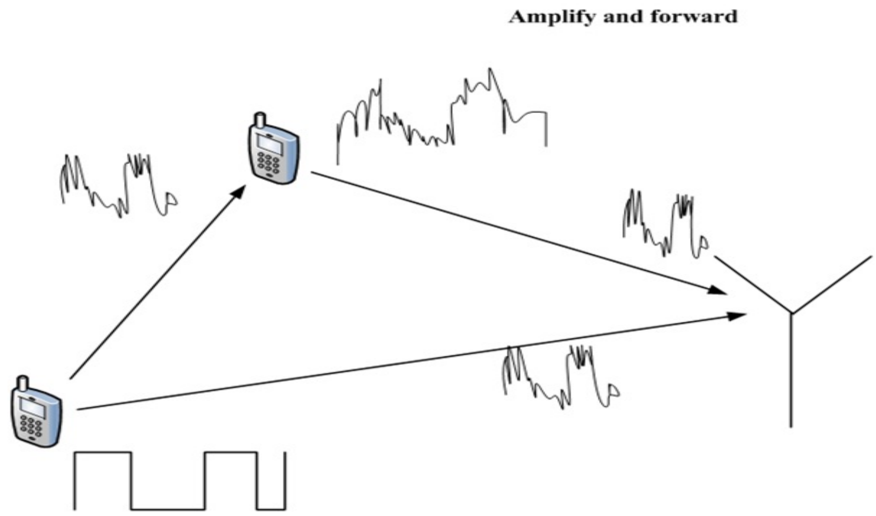

Figure 2.4: Amplify and Forward Method

2.4.2 Decode and forward Method

The first work proposing a detect-and-forward protocol for user cooperation was by Sendonaris, Erkip, and Aazhang [23][24]. Nowadays a wireless transmission is very seldom analogue and the relay has enough computing power, so Decode and Forward is most often the preferred method to process the data in the relay. 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 relay 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 relay station. Or if there is no such code implemented a checksum allows the relay 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 relay 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.

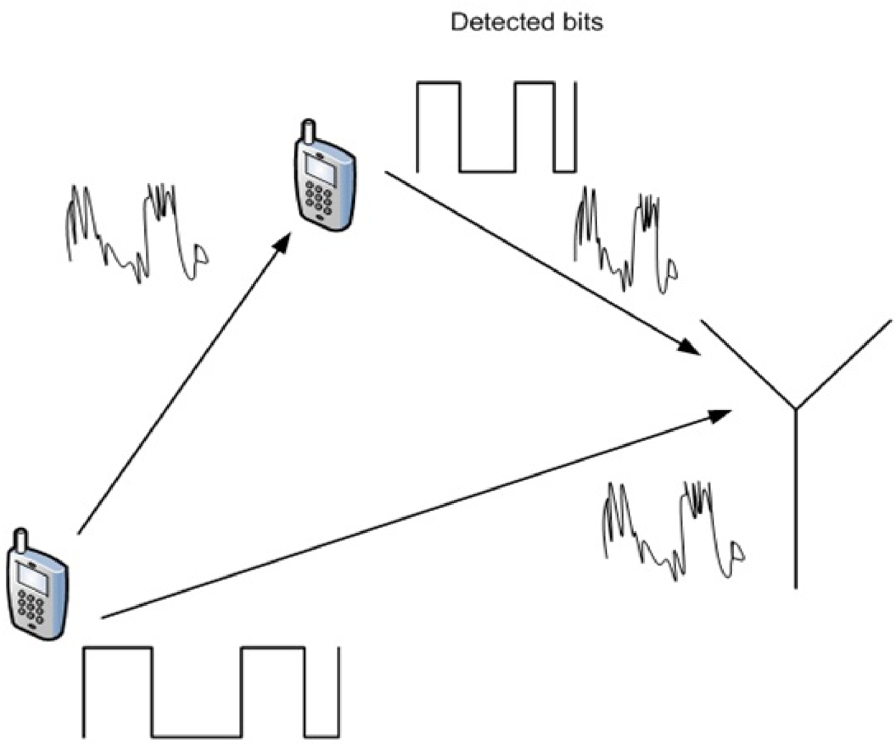

Figure 2.5: Decode and Forward Method

2.5 Pros and Cons of cooperation

The advantages and disadvantages of the cooperative communication are summarized below [25]:

2.5.1 Advantages of Cooperation

The key advantages of using relays in the system can be summarized as follows:

- **Performance Gains.** Large system-wide performance gains can be achieved due to diversity and multiplexing gains. These translate into higher capacity or better cell coverage.

- **Balanced Quality of Service.** Whilst in traditional systems users at the cell edge or in shadowed areas suffered from capacity and/or coverage problems, relaying allows to balance this discrepancy and hence give (almost) equal quality of service (QoS) to all users.

- **Infrastructure-Less Deployment.** The use of relays allows a system that has minimal or no infrastructure available prior to deployment. For instance, in disaster-struck areas, relaying can be used to facilitate communications even though the cellular system is nonfunctioning. For cellular system coupled with relays, the deployment and maintenance costs can be lowered.

- **Reduced Costs.** Compared to a purely cellular approach to provide a given level of QoS to all users in the cell, relaying is a more cost effective solution.

2.5.2 Disadvantages of Cooperation

Some major disadvantages of using relays in the system are given below.

- **Complex Schedulers.** A single cooperative relaying link is a trivial task, at system level with many users and relays this quickly becomes an arduous task.

As such, relaying requires more sophisticated schedulers since not only traffic of different users and applications needs to be scheduled but also the relayed data flows. Any gains due to cooperation at the physical layer dissipate rapidly if not handled properly at medium access and network layers.

- **Increased Overhead.** A full system functioning requires handovers, synchronization, extra security,etc. This clearly induces an increased overhead w.r.t to a system that does not use relaying.
- **Partner Choice.** To determine the optimum relaying and cooperative partner(s) is a fairly intricate task. Also, the complexity of maintaining such cooperative partnership is higher w.r.t. no cooperative relaying.
- **Increased Interference.** If the offered power savings are not used to decrease the transmission power of the relay nodes but rather to boost capacity or coverage, then relaying will certainly generate extra intra- and inter-cell interference, which potentially causes the system performance to deteriorate.
- **Extra Relay Traffic.** The relayed traffic is, redundant traffic and hence decreases the effective system throughput since in most cases resources in the form of extra frequency channels or time slots need to be provided.
- **Increased End-to-End Latency.** Relaying typically involves the reception and decoding of the entire data packet before it can be re-transmitted. If delay-sensitive services are being supported, such as voice or the increasingly popular multimedia web services, then the latency induced by the decoding may become detrimental. Latency increases with the number of relays and also with the use of inter-leavers, such as utilized in GSM voice traffic.
- **Tight Synchronization.** A tight synchronization is necessary for cooperation. This requires expensive hardware and large protocol overheads since nodes need to synchronize regularly by using some form of beaconing or other viable techniques.

2.6 Applications

- Cooperative sensing for cognitive radio

  In cognitive radio system, unlicensed secondary users can use the resources which are licensed for primary users. When primary users want to use their licensed resources, secondary users has to vacant these resources. Hence secondary users have to constantly sense the channel for detecting the presence of primary user. It is very challenging to sense the activity of specially distributed primary users in wireless channel. Spatially distributed nodes can improve the channel sensing reliability by sharing the information and reduce the probability of false alarming.

- Wireless Ad-hoc Network

  This is autonomous and self organizing network without any centralized controller or pre-established infrastructure. In this network randomly distributed nodes forms a temporary functional network and support seamless leaving or joining of nodes. Such networks have been successfully deployed for military communication and have lot of potential for civilian applications include commercial and educational use, disaster management, road vehicle network etc.

- Wireless Sensor Network

  Cooperative relaying can be used to reduce the energy consumption in sensor nodes, hence lifetime of sensor network increases. Due to nature of wireless medium, communication through weaker channels require huge energy as compared to relatively stronger channels. Careful incorporation of relay cooperation into routing process can selects better communication links and precious battery power can be saved.

2.7 Summary

In any wireless channel fading can be reduced by placing multiple antenna at transmitter and receiver(MIMO). But MIMO is not useful for all wireless communication, like in mobile communications, it is difficult to deploy more than one antenna due to size of mobile. These issues can be resolved if users are willing to share their local resources and cooperate in transmitting each other's messages. This is the essence of Cooperative communications. Cooperative communication has less error probability compared to non-cooperative communication or direct communication.

Chapter 3

Literature survey of Relay Selection Techniques

In cooperative communication, to choose the relay or partner 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.

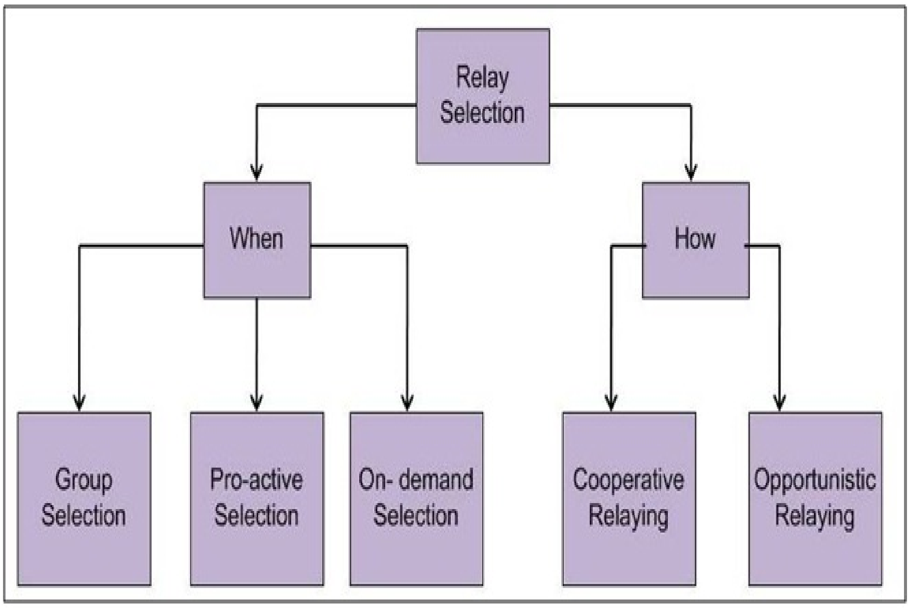

Figure 3.1: Relay selection

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

- Opportunistic Relay Selection
- Cooperative Relay Selection

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

- Measurement-based relay selection
- Performance-based relay selection
- Threshold-based relay selection

All these three approaches are opportunistic and follow a proactive selection approach.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 [12]

3.1 Measurement-based Relay Selection

Measurement-based relay selection approaches are characterized by requiring no topology information, being based only on local measurements of instantaneous channel conditions.[2],[3].Measurement-based approaches are able to select the best relay among N devices, but for this they may require 2N channel state estimations.

In measurement-based selection, each potential relay estimates channel conditions of source-relay and relay destination channels by using RTS/CTS signaling. CSI estimation is based on fading amplitudes between source-relay and relay-destination and on the expected performance of the source-relay-destination channel. After CSI estimation, each relay sets a transmission timer to a value inverse to the estimated CSI value. The timer with the best suitable CSI expires earlier, qualifying that device as relay. Devices in listening mode will back off as soon as they overhear a short duration packet sent by the qualified relay. To avoid the case of "hidden" relays, the qualified relay may request the destination to notify all the other potential relays about its transmission.

3.2 Performance-based Relay 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: In a first phase, sources transmit their required performance level, and in a second phase all potential relays estimates their channel conditions as well as performance level. However, estimation overhead may bring some limitations to performance-based approaches, and the transmission may still occur over the direct link if the performance conditions are not met.

3.3 Threshold-based Relay Selection

Threshold-based approaches rely on a certain threshold to reduce the number of competing relays, and thus reducing the overhead of channel estimations. This class of relay selection can be opportunistic or cooperative. The relay selection involves two phases. In a first phase, each neighbor compares the quality of signal it received from the source with a threshold such as SNR [4] or BER [8]. In a second phase, only relays who satisfied the threshold requirements will enter into relay selection according to the algorithm. For instance, the node with the maximum lower value of the SNR in the source-relay and relay-destination links is selected as relay.This category of schemes may lead to some complexity, for instance, when all M relays satisfy the threshold, there will be 2M channel estimations. Another problem is the choice of the threshold value; if it is fix then relay selection mechanism is unable to react to variations on channel conditions.

3.4 Adaptive Relay 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 [6].

The operation of adaptive relay selection approaches is as follows: in a first phase the destination compares the quality of received signal with a pre-defined threshold. If the quality of received signal is below that threshold, then the relay selection process is triggered. Adaptive schemes should address the transmission collision problem and should take more advantage of spatial diversity. Moreover, thresholds at destination need to be optimal to guarantee fast reaction to channel variations.

3.5 Table-based Relay Selection

Table-based approaches[9][10] 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.

The usage of RTS-CTS frames is also different. In [10], the cooperative-RTS which is sent by the source to the relays and by the latter to the destination to show their willingness to cooperate. If the destination finds that such cooperation is beneficial via both relays, it sends a cooperative-CTS to the source. Table-based approaches present degradation problems in the presence of moving nodes. Another problem with this class are the periodic broadcast and extra handshaking signals which can limit the efficiency.

3.6 Contention-based Relay 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. This class of relay selection works in two phases.

The operation of contention-based selection approaches is as follows:

In the first phase relays estimate their qualification. The nodes estimate local conditions, which are the relay position and degree [12]. If these estimations satisfy certain threshold then such relays are qualified relays for selection. In the second phase the relays select their contention window on the basis of priorities. For instance, the potential relays broadcasts their qualification, allowing other overhearing qualified relays to construct a global map of qualified relays and source-destination pairs, setting the priority level of each node.

The limitation of this class is the influence that the size of the contention window has in the relay selection. Moreover, since it follows a cooperative approach, there is the problem of overhead due to broadcast of qualification/nomination messages.

3.7 Multi-Hop Relay Selection

The most common relaying approach in the literature is to select a relay (or a set of relays) to help a transmission from a sender to a destination over a direct poor wireless link. When applied to multi-hop networks, this method requires the repetition of the relay selection procedure for each hop from sender to destination. However, such hop-wise cooperation can reduce network capacity.

The operation of multi-hop relay selection approaches is as follows:

Potential relays access routing information (from the local network layer) creating a limited image of the network beyond the adjacent wireless links (typical two hops). By overhearing transmissions over the identified network, potential relays may decide to relay overheard information to potential destinations, even in the absence of a direct link between the source and destination of the packet. This means that relays may have received the information to be relayed directly from the source or from other relays or intermediary nodes (routers).

In multi-hop relay selection, the destination node may receive more than two independent signals of the same packet e.g. directly via the source, via the intermediary node identified by the routing protocol and via the selected relay node. This extra spatial diversity increases robustness and performance. However, the price to pay is the extra network overhead to transmit redundant information, and the cross layering needed to collect routing information, which may not be updated with the frequency require to react in environments with mobile devices.

3.8 Summary

In summary, relay selection should be done by considering the following criteria:

Relay selection should support systems able to achieve a good balance between the performance of individual transmissions and performance of the overall network. Relays should be selected based on stable parameters, avoiding the usual channel state, signal to-noise ratio or packet error rate. Good relay selection schemes should be able to support multi-hop scenarios as well as scenarios with mobile nodes.

The choice of relay selection schemes should be able to make the best out of local opportunities, with the support of inter-relay cooperation. The usage of such opportunistic-cooperative relay selection schemes will provide the needed distributed intelligent to support relaying over large networks in the present of nodes with dynamic behavior.

Chapter 4

Relay selection schemes

4.1 Greedy and Exchange Algorithm

In wireless networks, choice of the relay and the allocation of power between the source and relay are very important task. Greedy and Exchange algorithm [18], can be used to select appropriate relay node in the co-operative environment in order to minimize the transmission power. For this relay selection, multi-source and multi-relay network is considered with M sources and N relays. Here it is assumed that, one source has only one partner to help for information transmission.

Basically this technique is consisting two phases: The one is Greedy phase and the other is Exchange phase. The relay allocation in greedy phase is known as intermediate relay allocation, which is denoted by H1. In Greedy phase, for the relay selection, power matrix is generated, in which transmission power for each source with every relay is calculated. Now for one source the relay is being selected, in such a way that the source-relay pair has minimum power consumption. Now for next source, it has N-1 relays are available for selection because the relay which was selected by previous source is not available for next source. In this way relay selection is done until all the source nodes have been allocated.

The relay allocation in exchange phase is known as final relay allocation, which is denoted by H2. In exchange phase, the maximum power consuming pair from greedy phase is selected. Then the source and relay pair from greedy phase, which can swap the relay to get the maximum power saving, is being found. If the source and relay pair is found, delete previous pair from H1, and add new pair in H2(final relay allocation) and H1 respectively. Repeat this process until H1 is empty.

4.1.1 System Model

Consider a multi-source and multi-relay network with M source nodes and N relay nodes. Here it is assumed that, direct transmission is not possible and one source has only one partner to help for information transmission, i.e. single relay selection. In this method, each source node is connected with one relay. The channels from source nodes to relays and the channels from relays to destination are unidirectional.

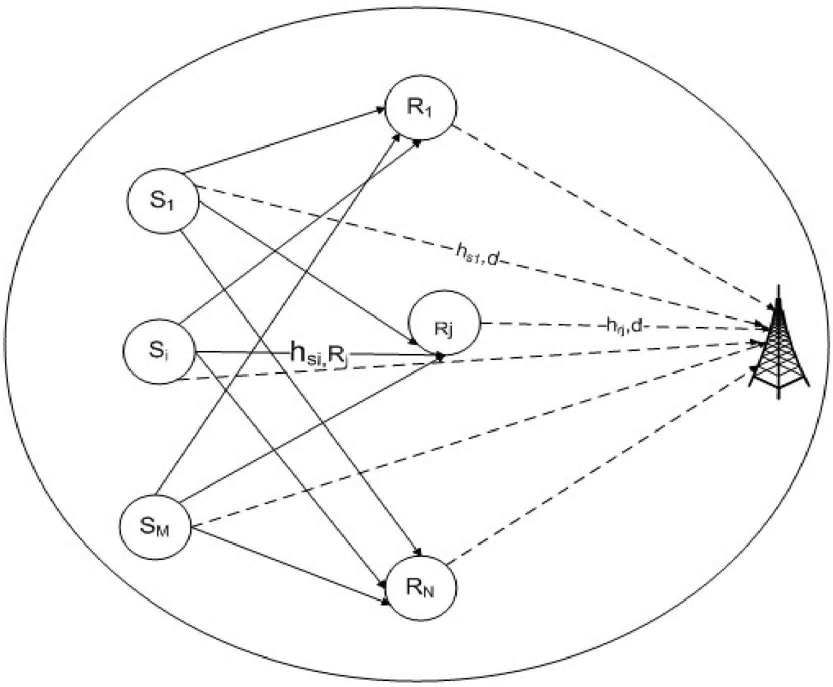

Figure 4.1: System model for Greedy and Exchange algorithm

4.1.2 Procedure

First of all, we need to calculate the total transmission power for each possible source and relay pair, and initialize the elements in the transmission power matrix P_{MXN}, which can be expressed as shown below,

$$\begin{bmatrix} P_{1,1} & P_{1,2} & ... & P_{1,N-1} & P_{1,N} \\ P_{2,1} & P_{2,2} & ... & P_{2,N-1} & P_{2,N} \\ ... & ... & ... & ... & ... \\ P_{M-1,1} & P_{M-1,2} & ... & P_{M-1,N-1} & P_{M-1,N} \\ P_{M,1} & P_{M,2} & ... & P_{M,N-1} & P_{M,N} \end{bmatrix} \tag{4.1}$$

where $P_{i,j}$ denote the minimum total transmission power when the i^{th} source cooperates with j^{th} relay to transmit the information.

The GAEA consists of two phases. In the first phase, namely greedy phase, ($Figure$ 4.2) the source and relay pair corresponding the minimum power in the matrix P_{MXN} is added into H1(intermediate allocation) until all the source nodes have been allocated.

In the second phase, namely exchange phase, based on H1, ($Figure$ 4.3) exchange is carried out M times for the total power reduction. Firstly, from H1, choose the source and relay pair (i, j) with maximum transmission power. Then, from H1 find the source and relay pair (I, J) which can swap the relay with (i, j) to get the maximum power saving. If the source and relay pair (I, J) is found, delete (i, j) and (I, J)from H1 , and add (i, J) and (I, j) in H2(final relay allocation) and H1 respectively. Notice that the source node I can choose to cooperate with the relays remaining from R or cooperate with the relay j. If the source and relay pair is not found, add (i, j) in H2, and delete (i, j) from H1. Repeat the process until H1 is empty. Finally, according to H2, the total transmission power can be achieved by summation of the corresponding elements of P_{MXN}.

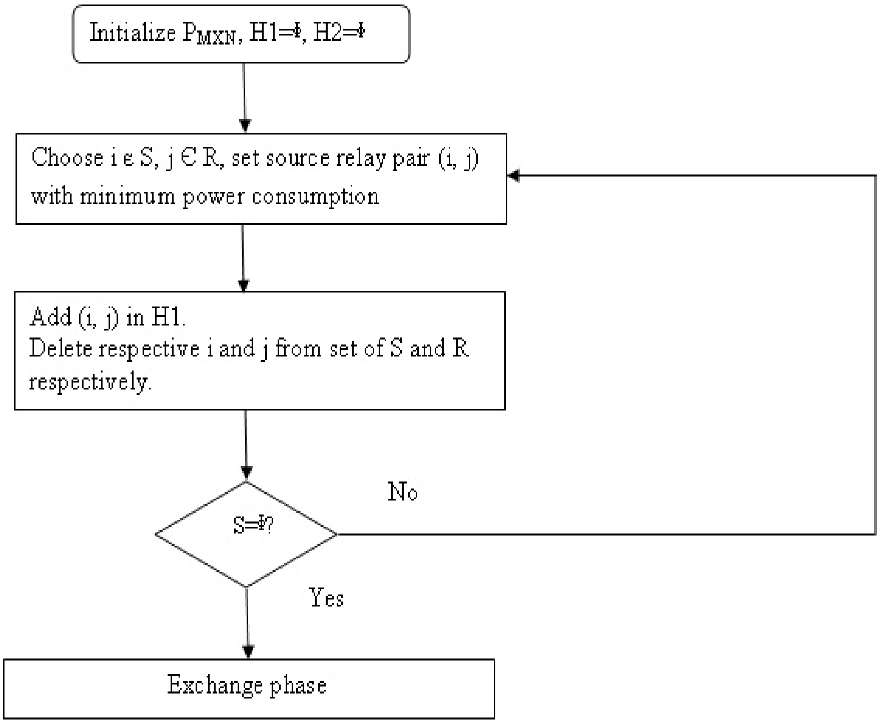

Figure 4.2: Flow diagram of greedy phase

4.1.3 Limitation of Greedy and Exchange Algorithm

From the simulation of the GAEA algorithm it has been found out that, it works well in DF-DT system. In DF-DT system, Direct Transmission from source node to destination is possible in addition to the relayed transmission. In the exchange phase of GAEA when a maximum power consuming pair (i, j) in H1 swaps its relay with other pair (I, J) forming pair (i, J), then source I remains without relay. So, now it can either chose to make pair with the relay j which is left by the source i, or it can co-operate with the remaining relays in the network, or can even opt for direct transmission.

The limitation with algorithm is that in case of DF system, where no direct transmission is possible, the exchange phase allocation tends to increase the total

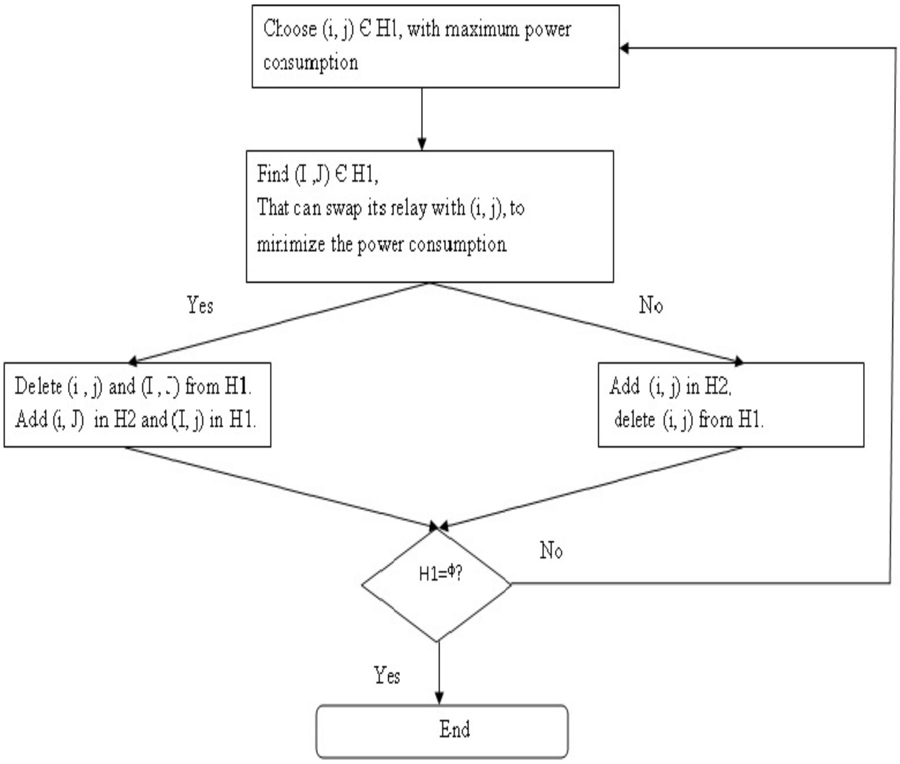

Figure 4.3: Flow diagram of exchange phase

power transmission. This is because, when pair (i, j) i.e maximum power consuming pair in H1, swaps its relay with (I , J) forming (i, J), then the source I is forced to make pair with j owing to the fact that there is no direct transmission possible and other relays are occupied by different sources. This can possibly increase the total power consumption of the source I transmission to the destination via relay j.

4.1.4 Modified Greedy and Exchange Algorithm

In order to overcome the above mentioned limitation of the GAEA algorithm, we propose a modified version of GAEA which eliminates the possibility of increase in power consumption in the exchange phase.

Modified GAEA uses an additional step compared to GAEA. This additional step consists of a check to identify whether the total power consumption due to source-relay allocation in Exchange Phase is greater than the corresponding power consumed in the Greedy phase or not. And, if it is so, then the instead of allocating source-relay pair as per H2(final allocation), relay selection is done based on H1(intermediate allocation) i.e the intermediate allocation in the Greedy Phase is kept as it is, and final relay selection is done on the basis of Greedy Phase result.

4.2 Parametric Relay Selection

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 work 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 [28].

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. Parametric relay selection, is used to select appropriate relay node in such a way that it can minimize the bit error rate & outage probability and maximize the data rate. It is obvious that, as no. of cooperating relay increases, total transmission power also increases. Thus the relay selection schemes may not be power efficient. so this scheme is used to reduce the bit error rate & outage probability. 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 or not, 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.

Parametric relay selection can either be single relay or multiple relay. In single relay selection scheme only a single relay is selected between transmitter and receiver among available all the relays in the network. So this scheme can also be considered as dual hope protocol. While in multiple relay selection, multiple relays are selected and can be considered as multihop protocol.

4.2.1 System model for parametric relay selection

Consider a single-source and multi-relay network is with one transmitter, one receiver and R relays. Each relay has one transceiver antenna which is used for transmission as well as receiver.

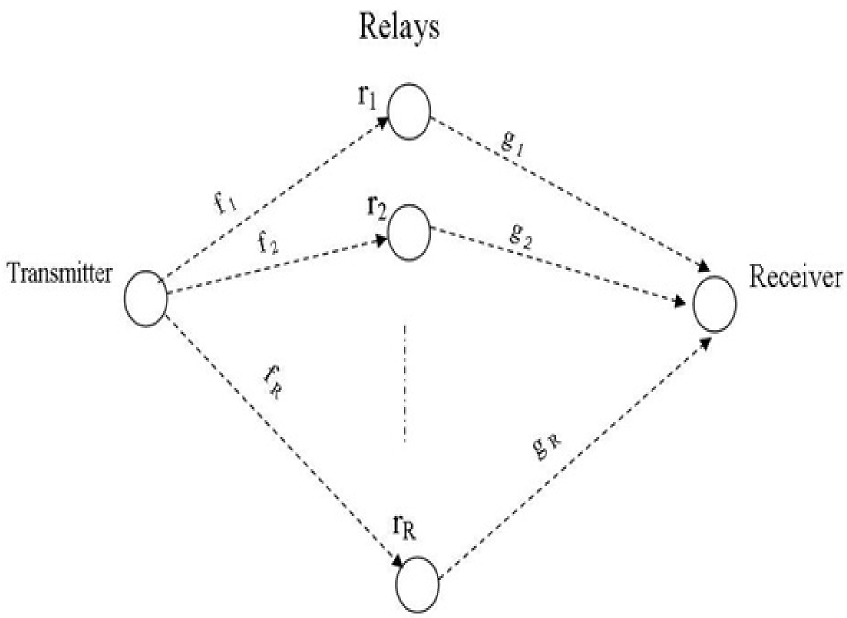

Figure 4.4: System model for parametric relay selection

The channel from the transmitter to Relay i is denoted by f_i and the channel from Relay i to the receiver is denoted by g_i. Here it is assumed that the relay i only knows its own channels f_i and g_i, but the receiver knows all channels f_1, . . . , f_R, g_1, . . . ,g_R.. All chanels are normalized independent, identically distributed, Rayleigh random variables, i.e., CN(0, 1). The power used at the transmitter, for each transmission is denoted by P and the power used at Relay i, for each transmission is denoted by P_i, respectively. Here it is assumed that all power levels have the same scaling, i.e., P/P_i is a constant. The selected relay cooperates with its full power and other with zero power .i.e no cooperation. When only Relay i cooperates, the received SNR is

$$SNR_i = \frac{|f_i g_i|^2 P P_i}{1 + |f_i|^2 P + |g_i|^2 P_i} \tag{4.2}$$

The received SNR at relay i shows, impacts of noise on the transmitted signal. Signal to noise ratio at relay i, depends on channel between transmitter to relay (f_i,) channel between relay to receiver.(g_i), transmission power used at transmitter (P) and transmission power used at relay (P_i).

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

4.2.2 Single relay selection

In single relay selection, only one relay can cooperate with full power, among all the relays we have in the network. In parametric relay selection, for single relay selection, there are four methods as follows:

- Best Worse Channel Selection
- Best Harmonic Mean Selection
- Best SNR Relay Selection
- Nearest Neighbor Selection

Best worse channel selection

The relay with max worse channel is selected [2]. For dual-hop protocols, each relay has two channels. From those two channels, the worst channel is selected. This process will be iterated for all relays in the network. Among all the worst channels the best channel will be selected. The selection function is,

$$h(f_i, g_i, P_i) = min\{P|f_i|^2, P_i|g_i|^2\} \tag{4.3}$$

Best harmonic mean selection

Harmonic mean is one kind of mean used to calculate average [2]. Harmonic mean H for 'n' numbers x_1,x_2,$x_3 x_n$ can be defined as the

$$\frac{1}{H} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{x_i} \tag{4.4}$$

To calculate the harmonic mean first calculate the arithmetic mean of the reciprocal of the numbers. Reciprocal of this average arithmetic will give the harmonic mean of the numbers. Arithmetic mean will be more impacted by the largest number from the available numbers and will almost neglect the effect of the smaller number. While harmonic mean will be impacted by the smaller numbers. In harmonic mean selection, harmonic mean of the two channels' qualities are calculated and the relay with the largest mean, is selected for cooperation. The selection function is,

$$h(f_i, g_i, P_i) = (P^{-1}|f_i|^{-2} + P_i^{-1}|g_i|^{-2})^{-1} \tag{4.5}$$

Best SNR relay selection

In best SNR relay selection, the relay whose path has the maximum SNR will be selected for the cooperation [26]. The selection function for best selection SNR scheme is given as

$$h(f_i, g_i, P_i) = \frac{|f_i g_i|^2 P P_i}{1 + |f_i|^2 P + |g_i|^2 P_i} \tag{4.6}$$

Nearest Neighbor Selection

In nearest neighbor selection, the relay that is the nearest to the base station is selected [27]. Here "The nearest relay" is not the spatially nearest relay to the transmitter or receiver, but the relay with the strongest channel to the transmitter or receiver means the relay with largest $p|f_i|^2$ or $p_i|g_i|^2$. The selection function for the nearest neighbor relay selection scheme is given as

$$h(f_i, g_i, P_i) = max\{P|f_i|^2, P_i|g_i|^2\} \tag{4.7}$$

4.2.3 Multiple relay Selection

In multiple relay selection, more than one relay can cooperate, among all the relays we have in the network [29]. The cooperating relay will cooperates with full power. So the power required to transmit the information will be more as compared to single relay selection. As no. of cooperating relay increases, the total power also increases, so this scheme is not so power efficient.

The relay selection procedure is shown in Figure 4.5

First, SNR from equation (4.2) of all relays are calculated. Then the receiver finds the relay k whose SNR is highest among all relays. The relay selection function h(f,g,p) for all relays are calculated

$$h(f_i, g_i, P_i) = \frac{|f_i| \sqrt{1 + |f_i|^2 P}}{|g_i| \sqrt{P_i}} \tag{4.8}$$

Now receiver finds h_{th}, whose value is in between $h_k < h_{th} < h_{k+1}$, means it lies between the value of relay selection function of the relay with highest SNR and the relay selection function of the relay which is next to the relay with highest SNR. If the relay whose SNR is highest, is last in the network, then assume $h_{k+1} = -\infty$.

Now each relay compares its own relay selection function with h_{th}. The relays whose h function are higher than h_{th} are selected for cooperation.

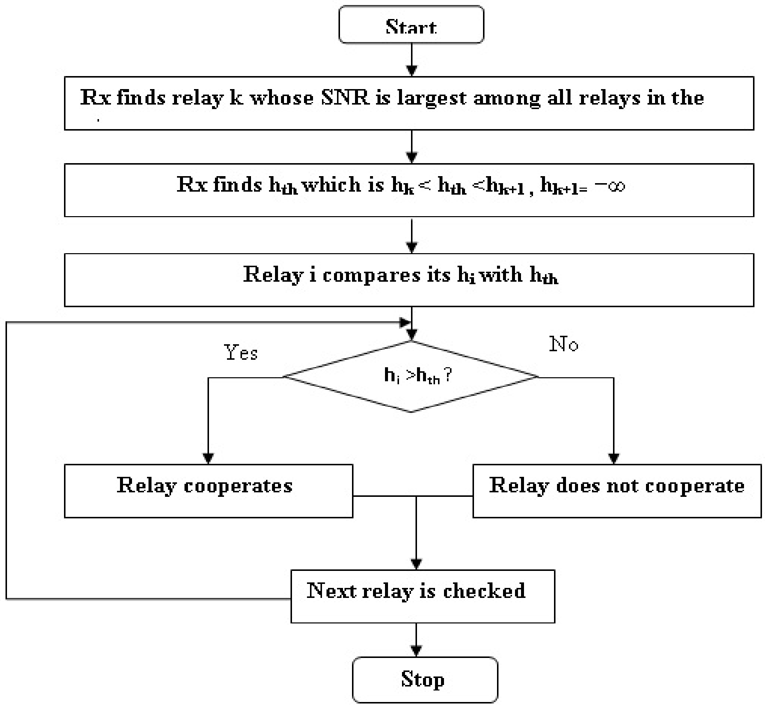

Figure 4.5: multiple relay selection flow diagram

4.3 Summary

This chapter covers two relay selection schemes. One is the greedy and exchange algorithm ($GAEA$) and the other is parametric relay selection.

GAEA can be used to minimize the transmission power. GAEA consists of two phases: Greedy phase (intermediate allocation) and Exchange phase (final allocation). In order to minimize the maximum power consuming source-relay pair of greedy phase, exchange phase is used. In exchange phase, maximum power consuming source relay pair can swap its relay with another pair of greedy phase, in order to minimize the transmission power. By doing this, it will unknowingly increases the total power consumption of the network. So that modified GAEA is developed, which overcomes the limitation of GAEA.

Parametric relay selection can be used to minimize the bit error rate & outage probability and maximize the data rate by using single relay selection and multiple relay selection.In single relay selection, only single relay can cooperate. Single relay selection consisting four schemes named Best worse channel selection, Harmonic mean selection, Best SNR selection & nearest neighbour selection. In multiple relay selection more than one relay can cooperate, within the network.

Chapter 5

Simulation and Results

5.1 Simulation of Greedy and Exchange Algorirhm

Simulation of GAEA algorithm is performed in simulation tool MATLAB. In DF environment, assuming that the power allocation is already done; we consider 5 sources and 5 relays for the simulation purpose, which can be changed as per requirement later on. Initially output of GAEA code is shown, and then same code is run for 5 consecutive times to check out the limiting effect of the GAEA. Later on, code for Modified GAEA is shown and the results of GAEA and Modified GAEA are compared.

Total power Greedy Phase = 51.1532

Table 5.1: The Greedy Phase intermediate relay allocation

source	relay	power consumption
2	5	1.0714
1	2	2.9262
3	1	3.8096
4	3	14.5613
5	4	28.7848

Total power Exchange Phase = 55.2664

Table 5.2: The Exchange Phase Final relay allocation

source	relay	power consumption
2	5	1.0714
5	1	18.9708
4	3	14.5613
3	2	16.4064
1	4	4.2566

The above output shows the source-relay pair and their corresponding power consumption. Total power Greedy Phase and Total power Exchange Phase are the total transmission power in Greedy Phase and Exchange Phase respectively.

As seen from Table 5.1 the maximum power consuming source-relay pair is 5-4 in H1 consuming 28.7848 unit power. In exchange phase as show in Table 5.2, source 5 exchanges it relay with source 3 making pair source-relay 5-1 consuming 18.9708 unit power which is less than pervious pair 5-4. But, though we succeeded in reducing power consumption of source 5, exchange phase has unknowingly increased power consumption of source 3 from 3.8096 to 16.4064 units which in turns increases the total power transmission.

As shown in Figure 5.1The code is run for 5 consecutive times in order to see the effect of power level of Greedy Phase and Exchange Phase; and the corresponding results have been shown in the form of Bar-graph below.

The careful observation of the above graph shows that initially in the second, forth and fifth run the power in Exchange Phase is effectively reduced by GAEA algorithm but in first and third run, it fails to do so. The reason for this is, Exchange phase's attempt to minimize the power consumption of maximum power consuming source relay pair by relay exchange, has increased the overall power consumption. This can be seen in first and third run where brown stripes are higher than blue strips.

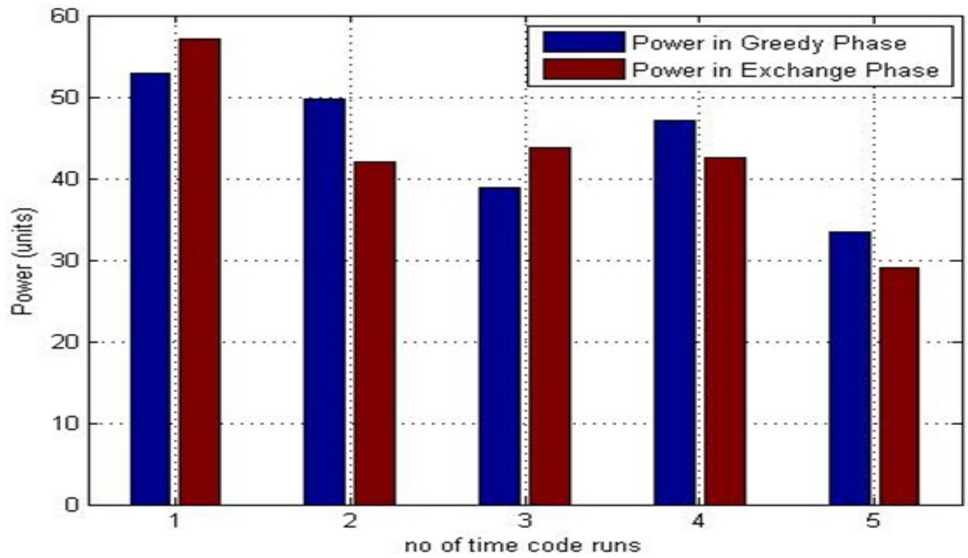

Figure 5.1: Bar-graph of GAEA Simulation

5.2 MATLAB Simulation of Modified GAEA

Total power Greedy Phase = 51.1532

Total power Exchange Phase = 55.2664

Modified Exchange Phase = 51.1532

As seen from the above output(Table 5.3), the maximum power consuming source-relay pair is 5-4 in H1 is consuming 28.7848 unit power. In exchange phase (Table 5.4), source 5 exchanges its relay with source 3 making pair source-relay 5-1 consuming 18.9708 unit power which is less than pervious pair 5-4. But, though we succeeded in reducing power consumption of source 5, exchange phase has unknowingly increased power consumption of source 3 from 3.8096 to 16.4064 units which in turns increases the total power transmission.Hence relay selection is not made on the basis of H2, but it is made on the basis of H1 i.e intermediate allocation in the Greedy Phase.

Table 5.3: The Greedy Phase intermediate relay allocation

source	relay	power consumption
2	5	1.0714
1	2	2.9262
3	1	3.8096
4	3	14.5613
5	4	28.7848

Table 5.4: The Exchange Phase Final relay allocation

source	relay	power consumption
2	5	1.0714
5	1	18.9708
4	3	14.5613
3	2	16.4064
1	4	4.2566

5.3 Comparison of GAEA and Modified GAEA:

The above simulated comparison of the GAEA and Modified GAEA shows that the power consumption in Modified GAEA never exceeds that in the Exchange Phase.

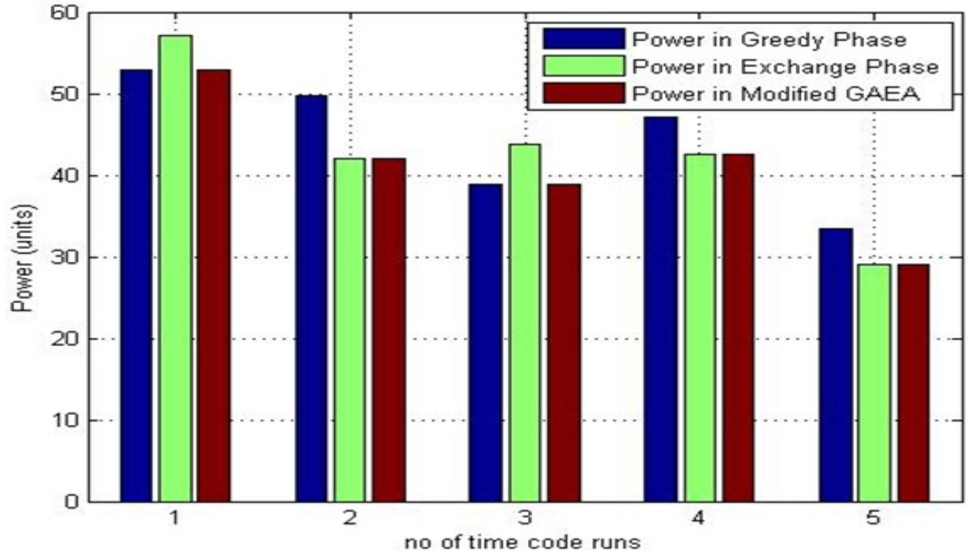

Figure 5.2: Comparison of GAEA and Modified GAEA

5.4 Simulation of parametric relay selection

For simulation of single relay selection as well as multiple relay selection technique, we have used MATLAB as software platform. 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.

Table 5.5: Simulation Parameters

Channel type	i.i.d CN $\sim$ (0,1)
Noise power	2dB
Modulation scheme	BPSK
No. of symbols	10000
Normalization constan	$\sqrt{\frac{1}{2}}$

5.4.1 Simulation of Single relay selection

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.

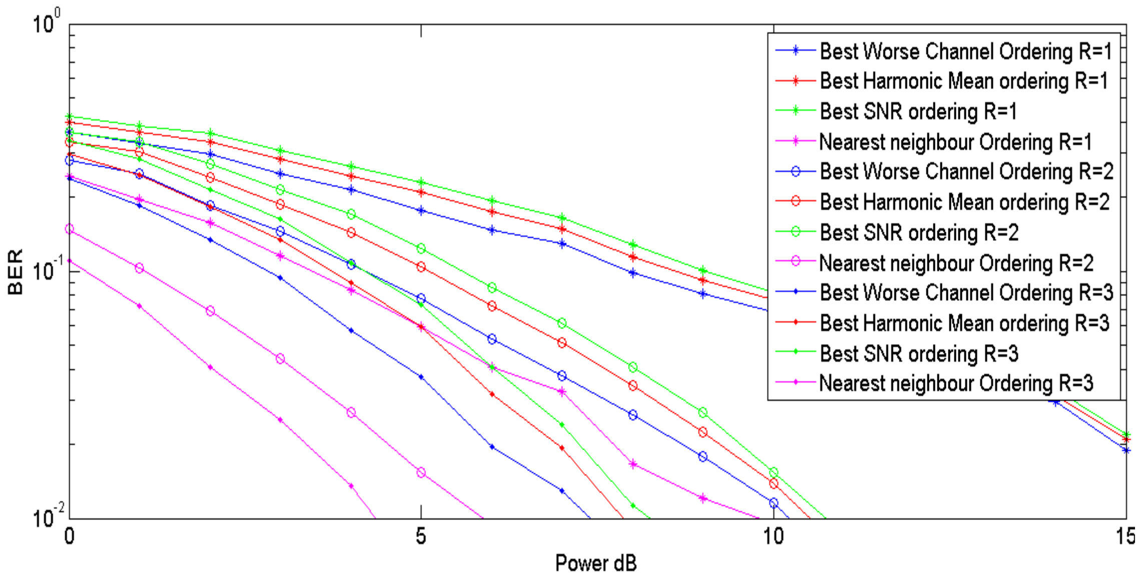

Figure 5.3: Comparison of BER performance for single relay selection schemes w.r.t power

Figure 5.3 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 network 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 neighbour selection. It can be observed that, the performance of Nearest neighbour selection is best among all four schemes.

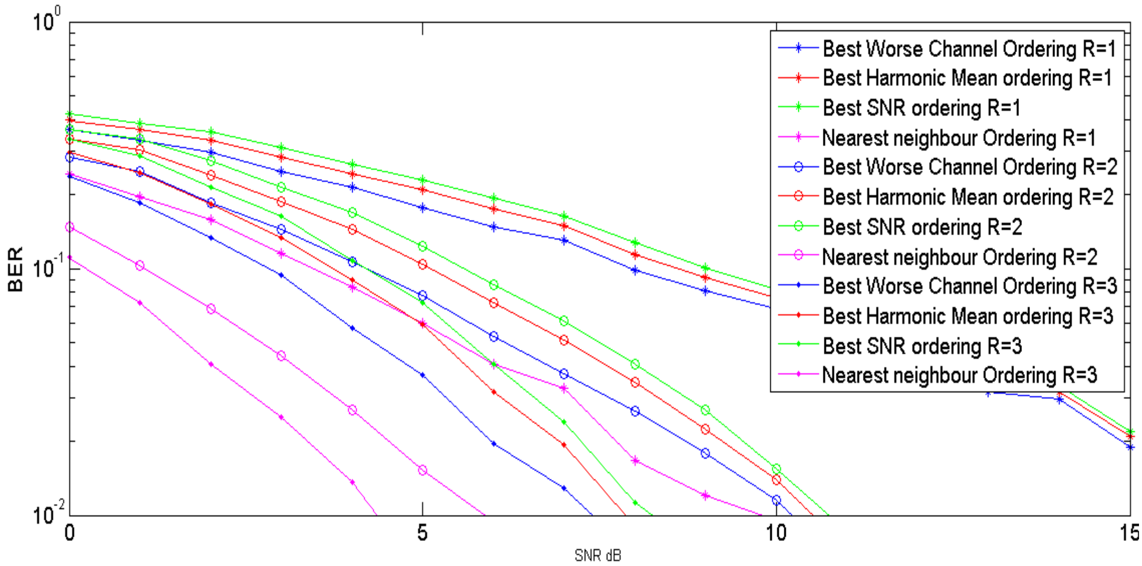

Figure 5.4: Comparison of BER performance for single relay selection schemes w.r.t SNR

Figure 5.4 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 network 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 neighbour selection. It can be observed that, the performance of Nearest neighbour selection is the best among all four schemes.

Figure 5.5 and figure 5.6 shows the plot of P_{outage} versus Power and P_{outage} versus SNR respectively. Probability of outage can be calculated by applying the condition that if instantaneous SNR is greater than given threshold SNR then channel is not considered in outage. And similarly, if it is less than threshold SNR it is considered in outage. We can see from graph that, as number of relays are increased then probability of outage decreases.

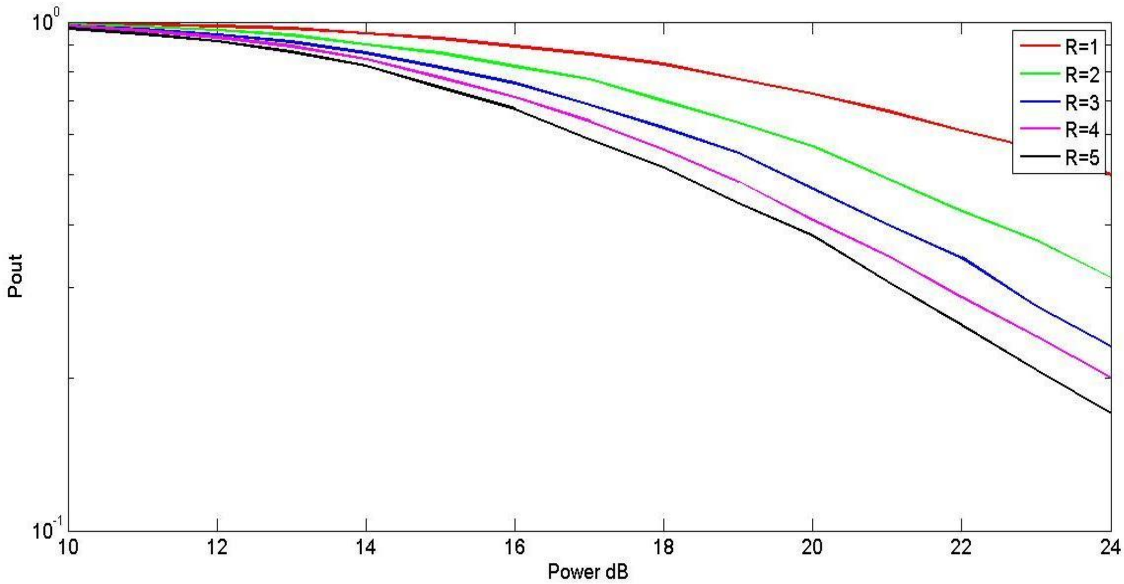

Figure 5.5: Comparison of P_{outage} performance for single relay selection schemes w.r.t power

Figure 5.5 shows the plot of P_{outage} versus Power for nearest neighbour selection scheme with varying number of relays from 1 to 5. From figure, it is clear that if we consider power level 16 db, we get P_{outage} 0.898, 0.8206, 0.7604, 0.7054 and 0.6745, for Relays 1,2,3,4,and 5 respectively in the network. So we can clearly observe that as the number of relay increases in the network, P_{outage} decreases and performance of the network will be better.

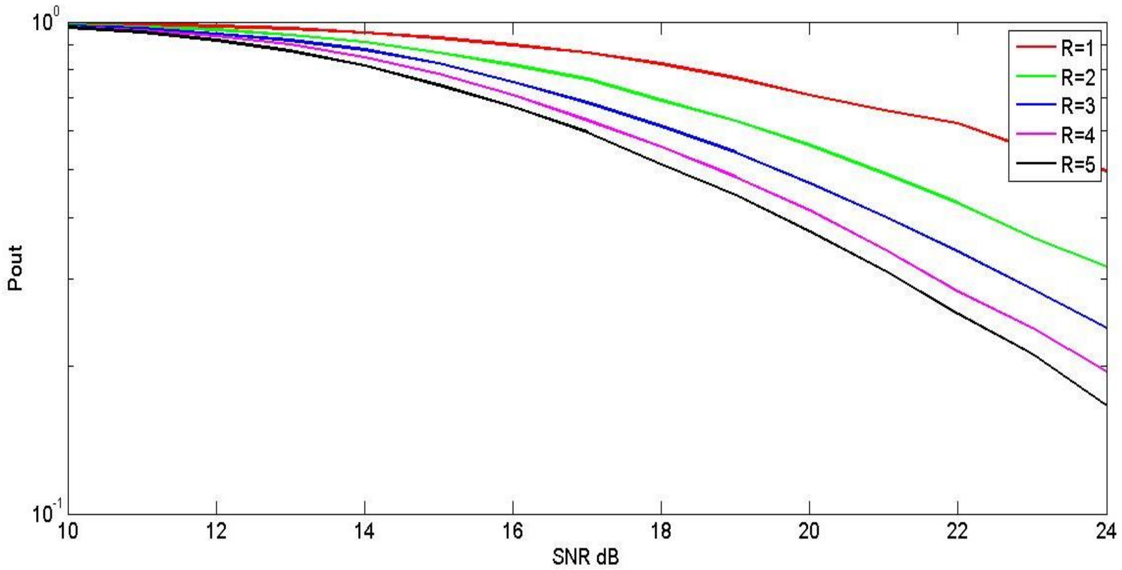

Figure 5.6: Comparison of P_{outage} performance for single relay selection schemes w.r.t SNR

Figure 5.6 shows the plot of P_{outage} versus SNR for nearest neighbour selection scheme with varying number of relays from 1 to 5. From figure, it is clear that if we consider SNR level 16 db, we get P_{outage} 0.8979,0.8179,0.7603,0.7126 and 0.6676 ,for Relays 1,2,3,4,and 5 respectively in the network. So we can clearly observe that as the number of relay increases in the network, P_{outage} decreases and performance of the network will be better.

Figure 5.7 and 5.8 shows the plot of data rate versus power and data rate versus SNR. The data rate of any system depends on the maximum channel capacity. If we can achieve data rate equal to maximum channel capacity then the data rate can be maximum. The maximum channel capacity can be calculated by

$$C = W \log_2(1 + S/N) \tag{5.1}$$

Here W is considered 1 MHz which is Bandwidth for system. S/N is SNR for transmitter. From equation and fig it can be observed that as power increases the Data rate or maximum channel capacity is increased.

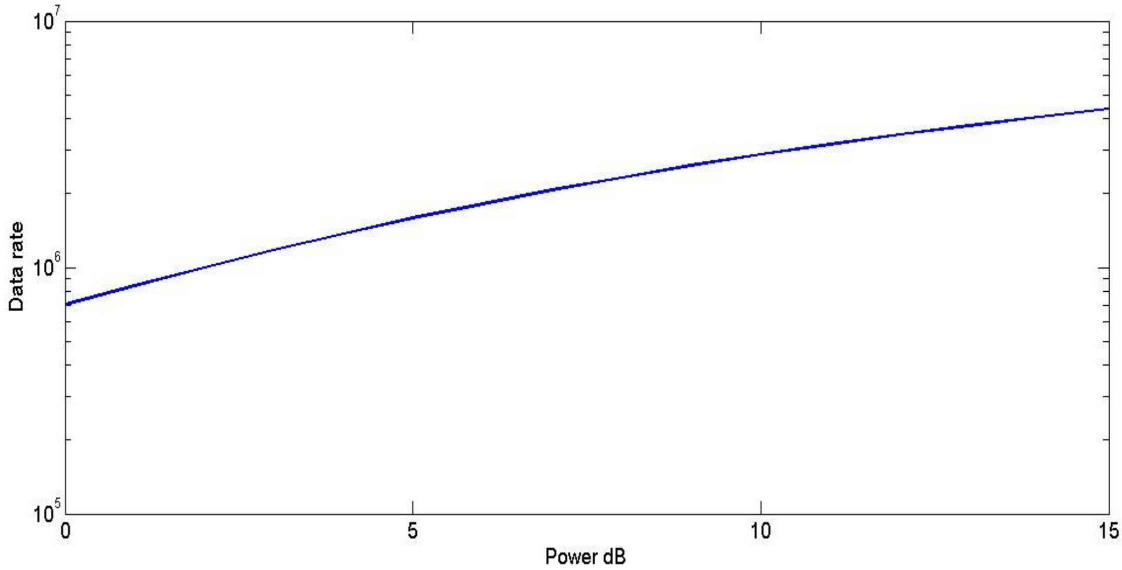

Figure 5.7: Comparison of Data rate performance for single relay selection schemes w.r.t power

Figure 5.7 shows the plot of data rate versus power for nearest neighbour selection scheme. From figure, it is clear that for power levels 5 db and 10 dB we get data rate $1.583(10^6)$ and $2.87(10^6)$ respectively in the network. So we can clearly observe that as power level increases data rate also increases.

Figure 5.8 shows the plot of data rate versus SNR for nearest neighbour selection scheme. From figure, it is clear that for power levels 5 db and 10 dB, we get data rate $2.057(10^6)$ and $3.459(10^6)$ respectively in the network. So we can clearly observe that as power level increases data rate also increases.

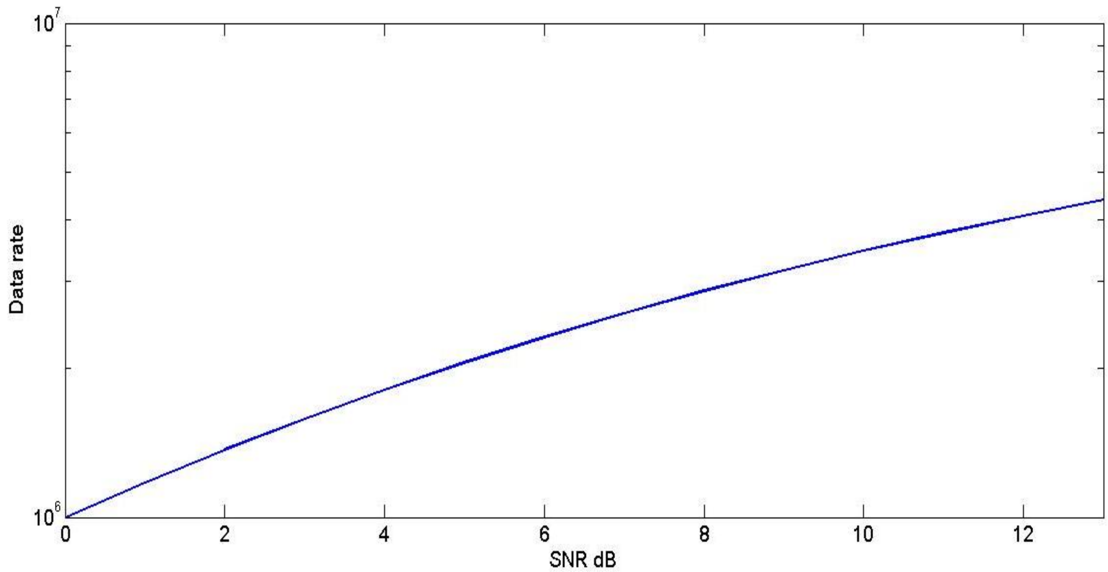

Figure 5.8: Comparison of Data rate performance for single relay selection schemes w.r.t SNR

5.4.2 Simulation of multiple relay selection

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 10 to 24 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 5.9 shows the plot of BER versus power for multiple relay selection, with varying number of relays from 1 to 5. From figure, it is clear that if we consider power level 15 db, we get BER 0.1191,0.0723,0.0484,0.0313 and 0.0243 ,for Relays 1,2 ,3 ,4 and 5 respectively. So we can clearly observe that as the number of relays increases in the network, BER decreases.

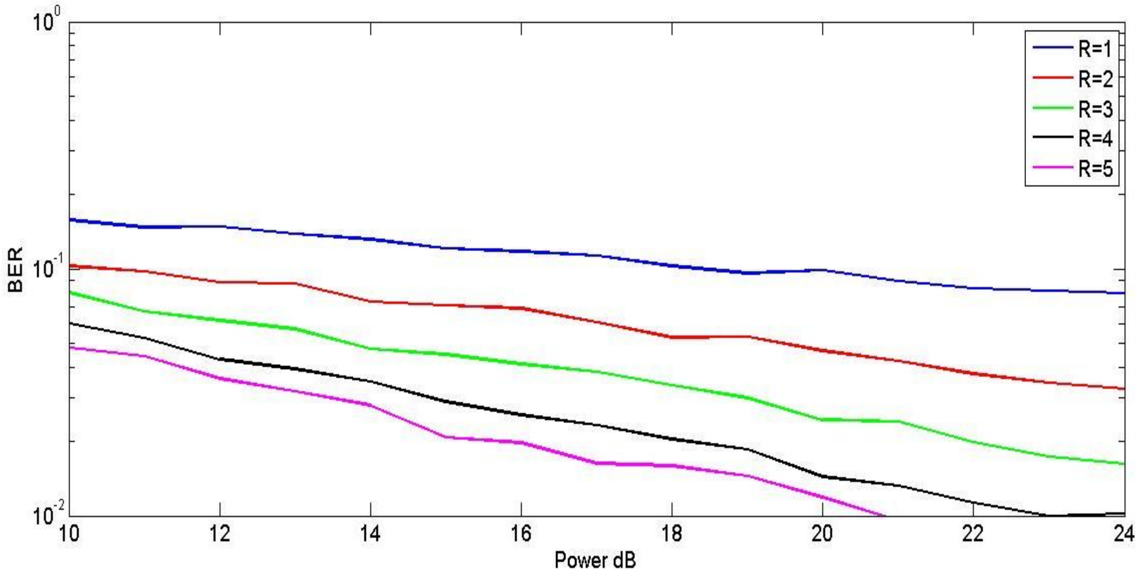

Figure 5.9: BER performance for multiple relay selection scheme w.r.t power

Figure 5.10 shows the plot of BER versus SNR for multiple relay selection, with varying number of relays from 1 to 5. From figure, it is clear that if we consider SNR level 15 db, we get BER 0.1097 ,0.0595,0.0362,0.0245 and 0.0195 ,for Relays 1,2 ,3 ,4 and 5 respectively. So we can clearly observe that as the number of relays increases in the network, BER decreases.

Figure 5.11 and 5.12 shows the plot of P_{outage} versus Power and P_{outage} versus SNR. Probability of outage can be calculated by applying the condition that if instantaneous SNR is greater than given threshold SNR then channel is not considered in outage. And similarly, if it is less than threshold SNR it is considered in outage. We can see from graph that, as number of relays are increased then probability of outage is decreased.

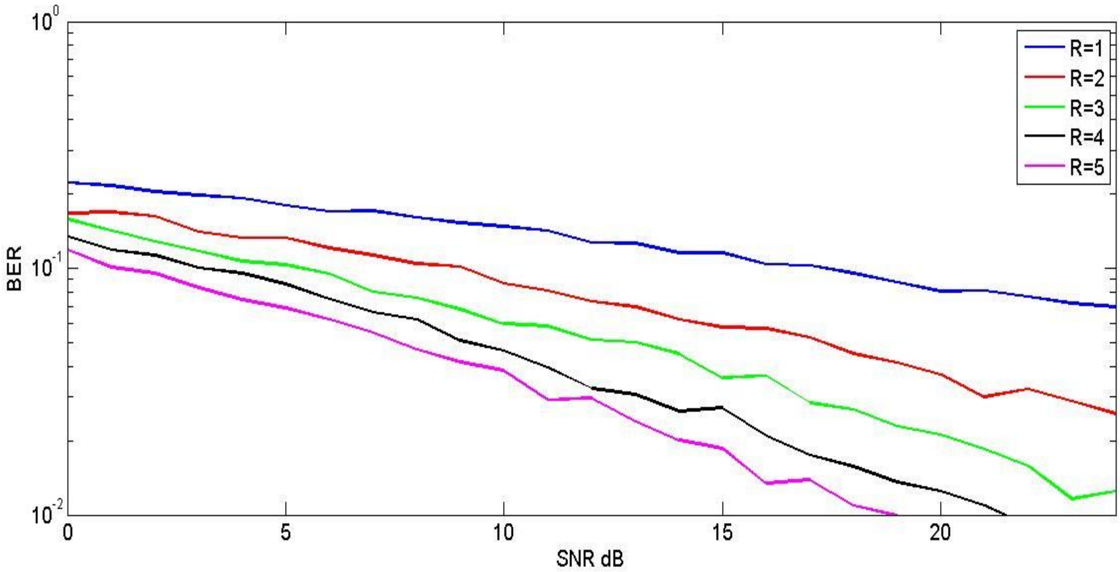

Figure 5.10: BER performance for multiple relay selection scheme w.r.t SNR

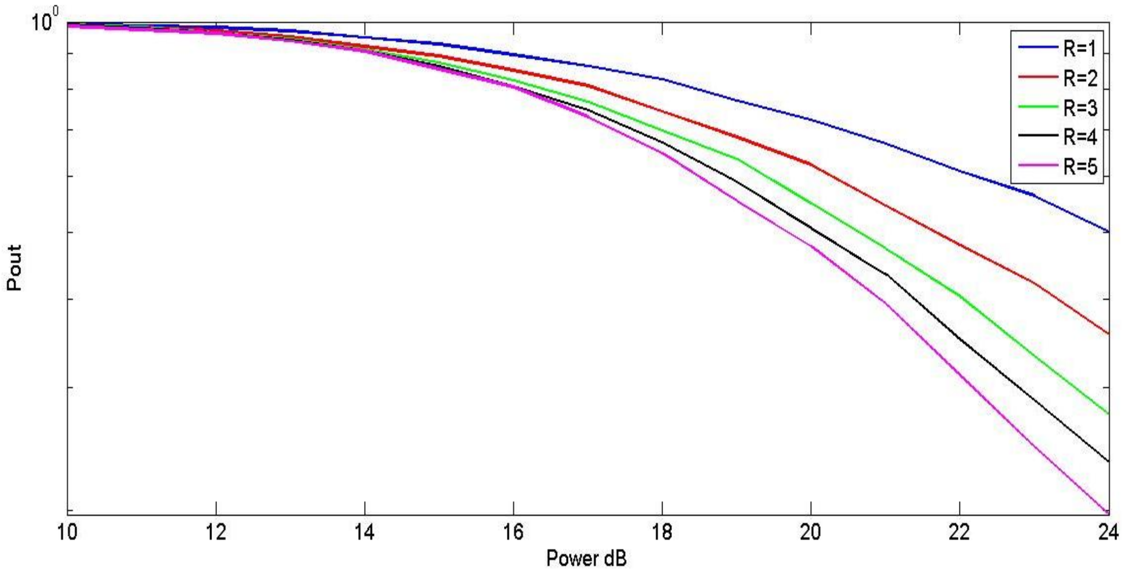

Figure 5.11: P_{outage} performance for multiple relay selection scheme w.r.t power

Figure 5.11 shows the plot of P_{outage} versus Power for multiple relay selection scheme. From figure, it is clear that if we consider power level 18 db, we get P_{outage} 0.8175, 0.7437, 0.6961, 0.669 and 0.6515 ,for Relays 1,2 ,3,4,and 5 respectively in the network. So we can clearly observe that as the number of relay increases in the network, P_{outage} decreases and performance of the network will be better.

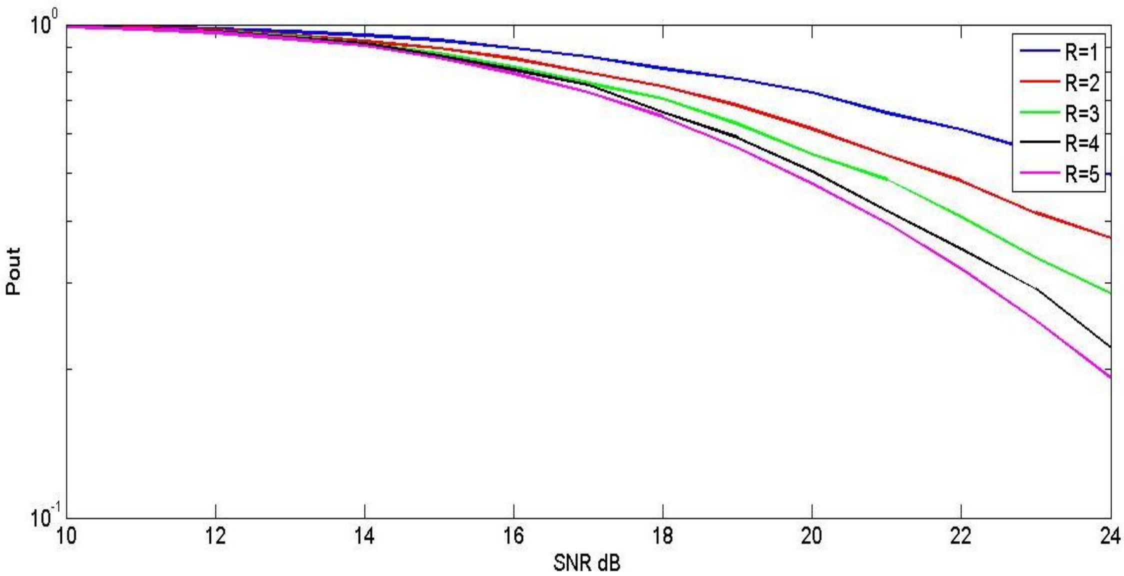

Figure 5.12: P_{outage} performance for multiple relay selection scheme w.r.t SNR

Figure 5.12 shows the plot of P_{outage} versus Power for multiple relay selection scheme. From figure, it is clear that if we consider power level 18 db, we get P_{outage} 0.8265, 0.7436, 0.6987, 0.6716 and 0.6497 ,for Relays 1,2 ,3,4,and 5 respectively in the network. So we can clearly observe that as the number of relay increases in the network, P_{outage} decreases and performance of the network will be better.

Figure 5.13 shows the plot of data rate versus power for multiple relay selection scheme. From figure, it is clear that for power levels 5 db and 10 dB we get data rate $1.583(10^6)$ and $2.87(10^6)$ respectively in the network. So we can clearly observe that as power level increases data rate also increases.

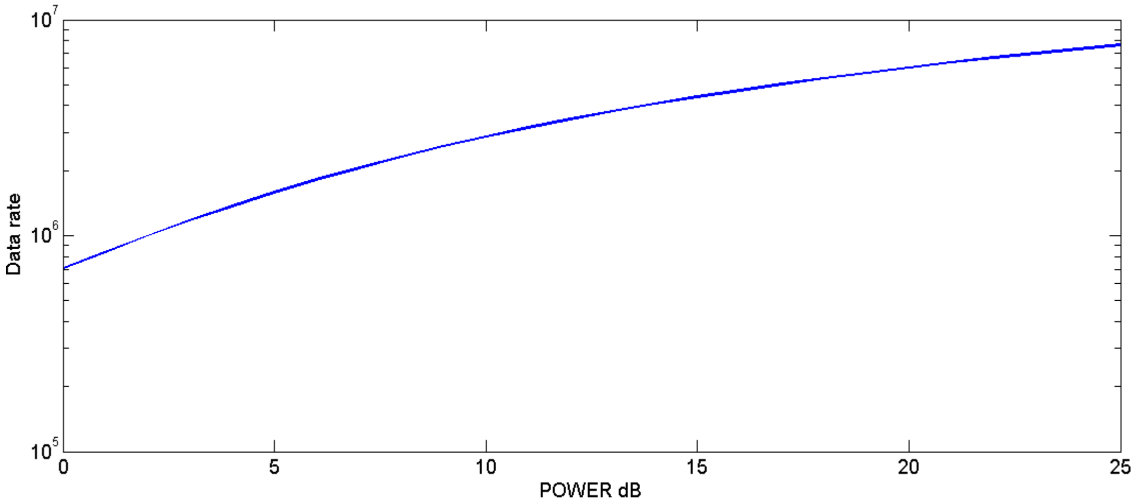

Figure 5.13: Data rate performance for multiple relay selection scheme w.r.t power

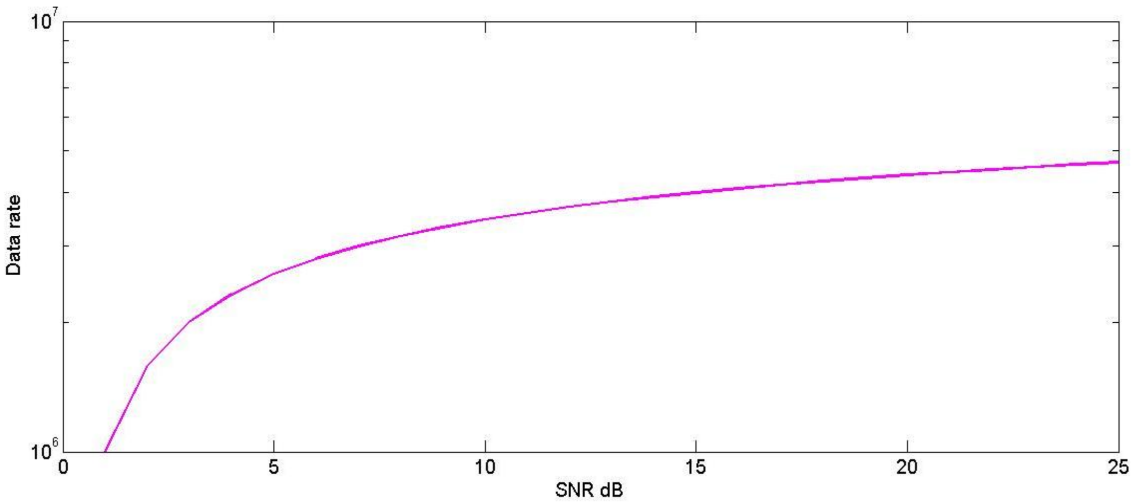

Figure 5.14: Data rate performance for multiple relay selection scheme w.r.t SNR

Figure 5.14 shows the plot of data rate versus SNR for nearest neighbour selection scheme. From figure, it is clear that for power levels 5 db and 10 dB we get data rate $2.057(10^6)$ and $3.459(10^6)$ respectively in the network. So we can clearly observe that as power level increases data rate also increases.

5.5 Summary

Simulations of both relay selection schemes,i.e GAEA & Parametric relay selection are performed in MATLAB.

The code of GAEA is run for 5 consecutive times to check out its limitations & we came to know that in order to minimize the maximum power consuming pair of greedy phase by using exchange phase, it unknowingly increases the total power of the network. So to overcome this limitation, logically modified GAEA is developed, which can be used to overcome this limitation.

In parametric relay selection, simulations of BER versus power & SNR, P_{outage} versus power & SNR and data rate versus power & SNR are performed, for single relay selection as well as multiple relay selection. Simulation results shows that, in single relay selection as well as in multiple relay selection, as the number of relay in the network increases, performance will be better. Among the four schemes of the single relay selection, nearest neighbour selection is the best.

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

By using cooperative diversity techniques, performance of wireless communication can be increased. With the help of cooperative diversity we can get results similar to the MIMO, but with less no of antennas. The diversity can be achieved by using relay along with source and destination in the network. The data is sent directly from the source to the destination or via the relay. Proper selection of the relay is a crucial task. In this, study of different relay selection techniques is done.

In this report, simulation of Greedy Exchange algorithm with limited no of sources and relays is done. This algorithm is basically used to minimize the total transmission power required to transmit the information. From the simulation results it has been concluded that, power consumption in Exchange phase is effectively reduced, but sometimes it fails to do so.

Modified GAEA algorithm developed as a part my thesis, which is an logical extension of the GAEA algorithm. This algorithms tends to minimize the overall power consumption and at the same time overcome the limitation of GAEA. The simulated results and the comparison also shows that Modified-GAEA algorithm can be effectively used for the Relay Selection in Wireless Networks and gives better and more optimized output as compared to GAEA algorithm.

Moreover, there are some of the relay selection techniques which are particularly used for minimizing the BER of a multi relay system. One can select single or multiple relays from a network as per the requirement. In single relay selection, there are techniques like Nearest neighbor ordering, Best worse channel ordering, Best harmonic mean ordering and Best SNR ordering. The simulation results for BER versus power and SNR, P_{outage} versus power and SNR and data rate versus power and SNR are obtained.From the simulation results it has been concluded that Nearest neighbor ordering is having best BER performance and P_{outage} performance with respect to power and SNR among all single relay selection technique. Certainly, single relay selection technique minimizes the BER compared to multiple relay selection. Data rate are almost same for both schemes which is desired.Probability of outage for single relay selection is lower compared to multiple relay technique.

6.2 Future Scope

While several key results for cooperative communication have already been obtained, many more issues remain to be addressed, and many possible directions for future research exist.

The GAEA can also be applied in the ad-hoc network where the sources can have the different destinations. At present it is considered that one source has only one relay as its partner to transmit information by using Decode and Forward protocol. In Future, simulation of different algorithms of multi relay selection with more than one relay for one source, different algorithms using different transmission protocol like Amplify and Forward can be done, and compared.

In parametric relay selection, simulation results shows that as transmission power increases, BER performance increases. So,there is a tread-off between power and BER. Simulation results also shows a tread-off between power and P_{outage}. So it would be interesting to extend the results of BER and P_{outage} with respect to power.

Simulation results shows that, performance of single relay selection is better compared to multiple relay selection, so it would be better for trying to improve the performance of multiple relay selection. It can be advantageous in case of relay failure.

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