Resource Optimization For Centralized Cooperative Relay Network

Major Project Report

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology

In

Electronics & Communication Engineering

(Communication Engineering)

By

Gandhi Shaishav Ajitkumar
11MECC03

Department of Electrical Engineering

Institute of Technology

Nirma University

Ahmedabad- 382 481

May 2013

Resource Optimization For Centralized Cooperative Relay Network

Major Project Report

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology

In

Electronics & Communication Engineering

(Communication Engineering)

By

Gandhi Shaishav Ajitkumar

11MECC03

Under the Guidance of

Prof. M. A. Upadhyay

Department of Electrical Engineering

Institute of Technology

Nirma University

Ahmedabad- 382 481

May 2013

Declaration

This is to certify that

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

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

Gandhi Shaishav Ajitkumar
11MECC03

Certificate

This is to certify that the Major Project entitled **"Resource Optimization For Centralized Cooperative Relay Network"** submitted by **Gandhi Shaishav Ajitkumar(11MECC03)**, towards the partial fulfillment 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	**Program Coordinator**
Prof. M. A. Upadhyay	**Dr. D. K. Kothari**
(Associate Professor, EC)	(Professor, EC)
HOD	**Director**
Dr. P. N. Tekwani	**Dr. K Kotecha**
(Professor, EE)	(Director, IT, NU)

Acknowledgements

I would like to express my gratitude and sincere thanks to Dr. P. N. Tekwani Head of Electrical Engineering Department and Dr. D. K. Kothari Coordinator M.Tech Communication Engineering program for allowing me to undertake this thesis work and for his guidelines during the review process.

I am deeply indebted to my thesis supervisors Prof. M. A. Upadhyay for their constant guidance and motivation. Without their experience and insights, it would have been very difficult to do quality work.

I wish to thank my friends of my class for their delightful company which kept me in good humor throughout the year.

Last, but not the least, no words are enough to acknowledge constant support and sacrifices of my family members because of whom I am able to complete the degree program successfully.

Gandhi Shaishav Ajitkumar
11MECC03

Abstract

The wireless radio channel suffers from fading. Time varying nature of the channel imposes restrictions on the achievable data rate. By effectively transmitting or processing (semi)independently fading copies of the signal, diversity is a method for directly combating the effects of fading. However, any type of diversity requires extra resources in the form of frequency, time or antenna. Multiple input multiple output systems (MIMO) has achieved higher through put suitable to cater the demands of next generation wireless applications. But MIMO requires extra hardware which makes it difficult for handhold or small wireless nodes in terms of cost, size and extra power requirement. Recently, cooperative communications have gained attentions as an emerging transmit strategy for future wireless networks. The basic idea is that the relay nodes can help the source nodes transmission by relaying the replica of the information. The cooperative communications efficiently take advantage of the broadcasting nature of wireless networks, as well as exploit the inherent spatial and multiuser diversities. To taste the flavour of cooperation, it is utmost essential to attract the nodes to operate cooperatively and optimize the resources (bandwidth, power) among the sources and relays. Techniques to stimulate the cooperation by optimizing the resources are discussed in this report. In this thesis, resource allocation is done for different situation like efficient allocation, fair allocation and to provide best quality of service(Qos). Simulation result shows cooperative communication provide higher data rate and also shows trade off between efficiency and data rate for different type of allocation.

Contents

List of Figures

List of Tables

Abbreviations

AF .... Amplify and Forward
DF .... Decode and Forward
Qos .... Quality of service
SNR .... Signal to Noise ratio

Chapter 1

Introduction

Now a day 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.

1.1 Wireless Communication

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. Recently, 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.

1.2 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 variation occurs in signal's amplitude, phase and angle of arrival.[1]

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.

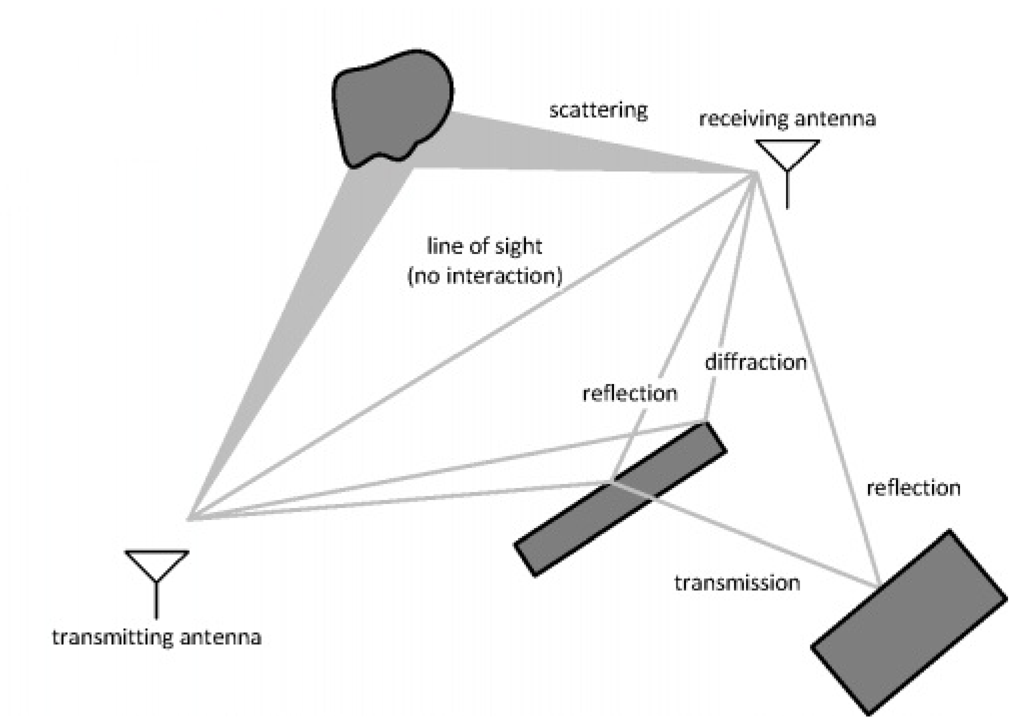

Figure 1.1: An example of different paths in a wireless channel[1]

Types of Fading

- **Large scale fading:** Average signal power attenuation due to motion over large area.

- **Small scale fading:** Large variation in the signal power due to small changes in the distance between transmitter and receiver is called small scale fading. It is also called Rayleigh fading if no line of sight (LOS) is there.
  Based on multipath delay spread two types are:

  i) **Flat fading:** It is occurs when signal bandwidth is less than channel bandwidth.

ii) **Frequency selective:** It is occurs when signal bandwidth is more than channel bandwidth.

Based on time variance two types are:

i) **Fast fading:** It is occurs when transmitted symbol time is more than coherence time, means channel changes many times during symbol is propagating.

ii) **Slow fading:** It is occurs when transmitted symbol time is less than coherence time, means channel does not change during symbol is propagating.

1.3 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.[2]

- **Antenna Diversity:** Multiple arrays 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.

1.4 Problem Statement

In cooperative communication source transmit the information in broadcast way. So many relay ready to help but wastage of power and bandwidth if relays transmit without controlled of power. When more nodes participate without controlled more power and bandwidth are used. For this reason optimization of resources is need. Nodes can be attracted for cooperating behavior if they find benefits i.e. saving of resources or higher data rate at the same power. In this project comparison of different type of resource allocation is analyze. For optimization Optim Tool is used. Now, to select the best relay which use optimal power and optimal bandwidth for cooperates concept of game theory can be used.

1.5 Overview of Thesis

The rest of the thesis are organized as follows:

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

Chapter 3:This chapter deals with introduction to different Relay Techniques and optimization technique.

Chapter 4:This chapter deals with discussion of simulation results of different types of resource allocation for different relay technique.

Chapter 5:This chapter comments on the results of the simulations and concludes with the further work on this project.

Chapter 2

Literature Survey

2.1 Introduction

Wireless communication systems are expected to provide a variety of services including video, voice and data. 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 increase by employing multiple transmit and receive antennas.

Transmit diversity is used for combining multi path fading in wireless communications, but use of multiple antenna in mobile terminal to achieve the transmit diversity is not feasible because of limited size of the mobile unit. To overcome this problem, cooperative diversity based on user cooperation proposed. In this user cooperation sender transmit data to the destination and other users for relaying to the destination.[3]

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. Also, in increasing demand for high data rates, fewer dropped calls, better quality of service, longer battery life and higher network user capacity paves the way for innovative techniques that improve link reliability and spectral efficiency. A signal transmitted through a wireless channel reaches 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 multi path 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, in the spatial dimension through multiple antennas, or the frequency dimension through frequency hopping. In all cases, diversity allows a user to average the fades such that a user sees a channel with lower variance. Normally, Spatial diversity is implemented with multiple antennas at the transmitter and receiver. Spatial diversity 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.

Multihop is used 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.

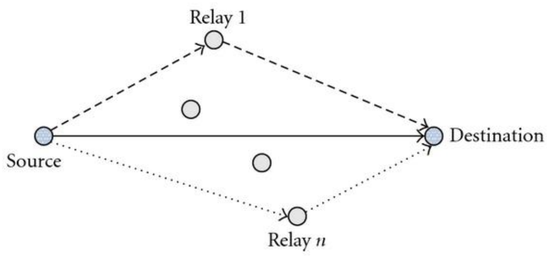

Figure 2.1: Cooperative communication[2]

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 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 other users while still being able to send their own data. This reciprocal arrangement is illustrated in Figure 2.2.[2]

Cooperation leads to interesting tradeoffs in data rates and transmit

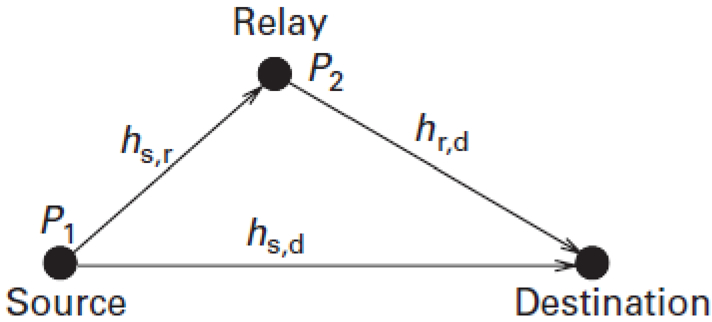

Figure 2.2: Relay Channel in cooperative communication[2]

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 and it is 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.

In phase 1, the source broadcasts its information to both the destination and the relay The received signal can be written as [2]

$$y_{s,d} = \sqrt{p}h_{s,d}x + n_{s,d} \tag{2.1}$$

$$y_{s,r} = \sqrt{p}h_{s,r}x + n_{s,r} \tag{2.2}$$

where,

P = Transmitted power at the source

x = Transmitted information symbol

$n_{s,d} = n_{s,r}$ = noise

$h_{s,d}$ = channel coefficients from the source to the destination

$h_{s,r}$ = channel coefficients from the source to the relay

In phase 2, the relay forwards a processed version of the sources signal to the destination, and this can be modeled as

$$y_{r,d} = h_{r,d}q(y_{s,r}) + n_{r,d} \tag{2.3}$$

where the function $q(\cdot)$ depends on which processing is implemented at the relay node.

Relay Techniques:

There are many cooperation strategies based on different relaying techniques,

1) Amplify-and-forward (AF)

2) Decode and forward (DF)

3) Coded cooperation

4) Compress-and-forward (CF)

2.2.1 Amplify-and-forward (AF)

In AF relay technique, the relay simply amplifies the received signal and forwards it directly to the destination without explicitly decoding the message. It is shown in figure2.3.

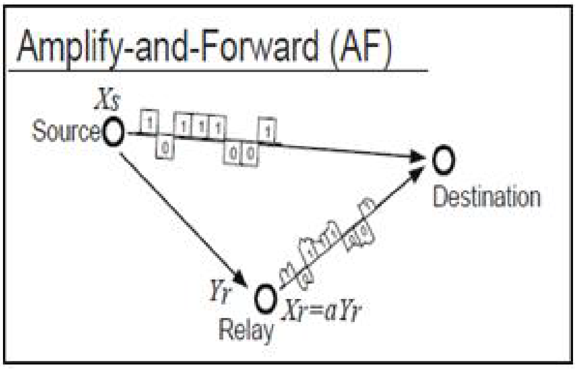

Figure 2.3: Amplify-and-forward (AF)[3]

Amplification factor is given by,

$$\beta = \frac{\sqrt{p}}{\sqrt{ph_{s,r}^2 + No}} \tag{2.4}$$

2.2.2 Decode and forward (DF)

In DF relay technique, the relay will decode and regenerate a new message to the destination in the subsequent time slot. At the destination, signals from both the source and the relay are combined to provide better detection performance. It is shown in figure2.4.

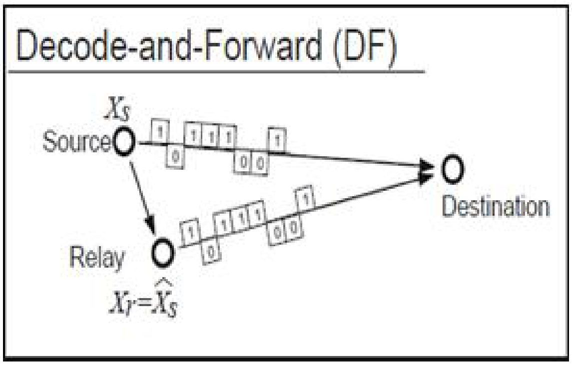

Figure 2.4: Decode and forward (DF)[3]

2.3 Pros and Cons of cooperation

2.3.1 Advantages of Cooperation

Advantages of using supportive, cooperative or spacetime relays in the system are below:

- **Performance Gains:** Large system-wide performance gains can be achieved due to pathloss gains as well as diversity and multiplexing gains. These translate into decreased transmission powers, 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 the roll-out of 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.

- **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.

2.3.2 Challenges of Cooperation

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

- **High data rate:** As relay is used for cooperation, the overall data rate at the destination through relay should be high.

- **Increased Overhead:**A full system functioning requires handovers, synchronization, extra security,etc. This clearly induces an increased overhead with respect 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 with respect to no cooperative relaying.

- **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.

- **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.

2.4 Applications

- Cooperative sensing for cognitive radio[4]
  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[5]

  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[7]

  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.

2.5 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

Resource Allocation

As in wireless communication resources, power and bandwidth, are main factor to distribute. To get the optimal result how to allocate the resources, so we can get maximum efficiency. Here we consider centralized relay network, which will allocate the resources optimally using optim tool. Relay techniques are used to cooperate in the network. Different types of resource allocation techniques proposed and also depend upon the data rates, utility of various application can decide to allocate the resources.

3.1 System Model

3.1.1 Direct and Cooperative Communication

AF Relay Technique is taking for analysis. In this system model relay is moving between source and destination in straight line as shown in figure3.1[10]. Distance between them is 50 meter. For path loss we take

$(\frac{do}{d})^a$[3]. here we consider signal experience rayleigh fading and do not suffer from inter symbol interference.

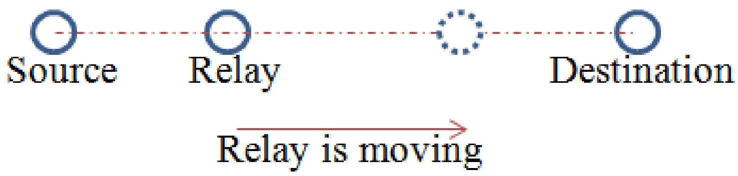

Figure 3.1: Source, relay and destination

The following equation are formula from shannon capacity for amplify and forward relay technique.
Data rate from source to destination.

$$R_{sd} = B * log_2(1 + SNR_{sd}); inbps \tag{3.1}$$

where, signal to noise ratio is as below.

$$SNR_{sd} = (\frac{P_s}{N_o}) * (\frac{d_o}{d_{sd}})^a \tag{3.2}$$

Where,

B = Bandwidth in Mhz

Ps = Transmitted power by source in watt

Pr = Transmitted power by relay in watt

No = Noise power in watt

do = Initial distance in meter

d_{sd} = Distance between source and distance in meter

a = Path loss exponent

d_{sr} = Distance between source and relay in meter

d_{rd} = Distance between relay and distance in meter

Data rate at destination for signal comes through relay,

$$R_{srd} = B * log_2(1 + SNR_{srd}); inbps \tag{3.3}$$

Where, signal to noise ratio for source to relay is given by,

$$SNR_{sr} = (\frac{P_s}{N_o}) * (\frac{d_o}{d_{sr}})^a \tag{3.4}$$

Signal to noise ratio for relay to destination is given by,

$$SNR_{rd} = (\frac{P_r}{N_o}) * (\frac{d_o}{d_{rd}})^a \tag{3.5}$$

Signal to noise ratio at destination is given by,

$$SNR_{srd} = \frac{SNR_{rd} * SNR_{sr}}{SNR_{sr} + SNR_{rd} + 1} \tag{3.6}$$

Analytically, optimal Power allocation to the source and relay can be minimize and given by,

$$P_s = \frac{2P\sqrt{1 + 2P\frac{h_{rd}}{N_o}}}{\sqrt{1 + 2P\frac{h_{sr}}{N_o}} + \sqrt{1 + 2P\frac{h_{rd}}{N_o}}} \tag{3.7}$$

$$P_r = \frac{2P\sqrt{1+2P\frac{h_{sr}}{N_o}}}{\sqrt{1+2P\frac{h_{sr}}{N_o}}+\sqrt{1+2P\frac{h_{rd}}{N_o}}} \tag{3.8}$$

Where,

P = Total power

Channel gain,

$$h_{sr} = (\frac{d_o}{d_{sr}})^a \tag{3.9}$$

$$h_{rd} = (\frac{d_o}{d_{rd}})^a \tag{3.10}$$

3.1.2 Analysis of DF

Decode and forward relay technique is used for sending the data. For DF relay technique data rate at destination is given by,[3]

$$R = \min(R_{sr}, R_{rd}) \tag{3.11}$$

Analytically, Optimal Power allocation to the source and relay can be minimize and given by,

$$Ps = \frac{2P(\frac{h_{rd}}{No})}{\frac{h_{rd}}{No}+\frac{h_{sr}}{No}} \tag{3.12}$$

$$Pr = \frac{2P(\frac{h_{sr}}{No})}{\frac{h_{rd}}{No}+\frac{h_{sr}}{No}} \tag{3.13}$$

3.1.3 System Model

Here, in proposed system model there are four sources, two relay and a destination is considered. Sources and destination are fixed. Relay is moving as shown in figure 3.2. Source 1 and source 2 are sending data to the destination using relay 1. where as source 3 and source 4 are sending data using relay 2. Consider as centralized network if there are more than one relay then relay selection is done by base station. Base station calculate the path loss and other parameter for source, Then give information to the source about best relay for source. It is shown in below figure.

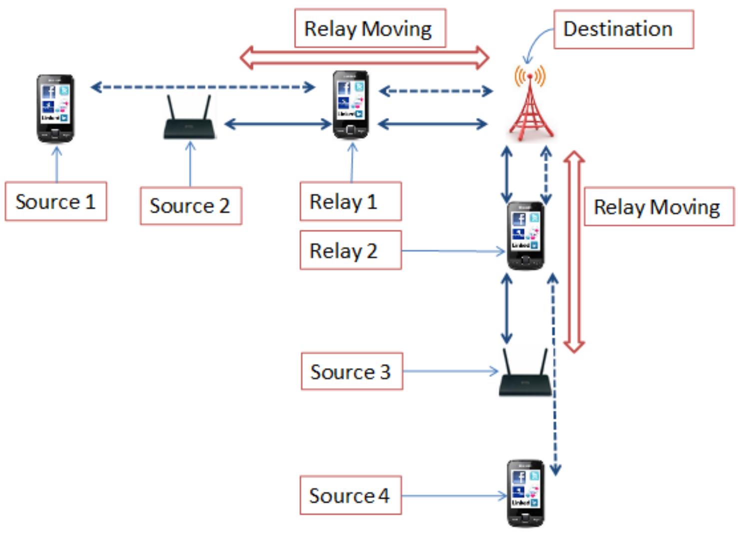

Figure 3.2: Four Source, Two relay and destination

Using these model Efficient allocation, fair allocation and to provide best Qos are used for resource allocation. These all are depend upon the channel gain. Here free space path loss model is considered, so depend upon the path loss weighing factor is given. for efficient as path loss is less weighting factor is less and vice versa. For fair allocation as path loss less more weighing factor and vice versa is given. To provide best Qos means if user demands for different application like video conference, surfing video, voice call and message. Depend upon the necessity and application weighing factor is given so user can get best service. to provide best Qos price is also main factor, more resource is given to the user who is ready to pay more price.

Efficient Allocation: In this technique resources allocate depend upon the path loss. First calculate the path loss, after then whose path loss high, less resources allocate. here resources allocate in the terms of weighing factor. For efficient as path loss is less weighting factor is less and vice versa.

Fair allocation: In this technique users should get minimum data rate. For this allocation of resources should be fair, so named fair allocation. As path loss less, more weighing factor and vice versa is given.

Best Qos: To provide best Qos means if user demands for different application like video conference, surfing video, voice call and message. Depend upon the necessity and application weighing factor is given so user can get best service. To provide best Qos price is also main factor, more resource is given to the user who is ready to pay more prices.

Now, main aim to maximize total data rate, Sum data rate maximization is given by, [10]

$$\max_{P,w} \sum_{i} R \tag{3.14}$$

For total power and bandwidth constraint are given below

with states that,

$$\sum_{i} Ps_i \leq P$$

$$\sum_{j} Pr_j \leq P$$

$$\sum_{i,j} ws_i + ws_j \leq w$$

Where, Ps_i is transmitted power by i^{th} source, Pr_j is transmitted power by j^{th} relay, ws bandwidth for source, wr bandwidth for relay.

3.2 Utility

There are many users in a network and need of every user is different. For different channel link users are ready to pay depend upon their need and channel condition. So utility represents the degree of satisfaction of a user as a function of the transmission rate.

Utility for different type of application utility proportional algorithm is derived in[11]. The existence of various types of user applications complicates the process of calculating the optimal rate allocation of a user for a specific aggregate price.

Take example to provide best Qos for best effort, delay tolerance and video streaming, utility are as,

Application type	Optimal rate allocation function	Optimal rate allocation function
Best Effort	$U_i(r_i) = \frac{log(\frac{r_i}{r^{max}})}{log(\frac{r^{max}}{r^{min}})}$	$r_i^*(\lambda) = r^{min} * (\frac{r^{max}}{r^{min}})^{\frac{1}{\lambda^i}}$
Delay Tolerance	$U_i(r_i) = \frac{log(r_i+1)}{log(r^{max}+1)}$	$r_i^*(\lambda) = (r^{max}+1)^{\frac{1}{\lambda^i}} - 1$
Video Streaming	$U_i(r_i) = \frac{1}{1+exp^{(-\alpha(r_i-\beta))}}$	$r_i^*(\lambda) = \frac{\alpha*\beta-log(\lambda^i-1)}{\alpha}$

Table I: The optimal resource allocation function for widely used types of applications

Where,

r^{max} = Maximum data rate

r^{min} = Minimum data rate

λ = Price

α and β are calibration parameters.

3.3 Optimization Tool

Optimization Toolbox provides widely used algorithms for standard and large-scale optimization. These algorithms solve constrained and unconstrained continuous and discrete problems. The toolbox includes functions for linear programming, quadratic programming, binary integer programming, nonlinear optimization, nonlinear least squares, systems of nonlinear equations, and multi objective optimization. To find optimal solutions, perform tradeoff analyses, balance multiple design alternatives, and incorporate optimization methods into algorithms and models it can be used.[12]

Key Features

- Interactive tools for defining and solving optimization problems and monitoring solution progress.
- Solvers for nonlinear and multi objective optimization.
- Solvers for nonlinear least squares, data fitting, and nonlinear equations.
- Methods for solving quadratic and linear programming problems
- Methods for solving binary integer programming problems

There are many types of solver in optimization tool, It are listed below. Linprog, fmincon, fminbnd, fminsearch, fminunc, quadprog, fseminf, lsqcurvefit, lsqlin, lsqnonlin, lsqnonneg.

These solvers are selected as type of objective function i.e. linear, quadratic and sum of square and type of constraint i.e. unconstrained, bound and linear.

In this project for analysis "linprog" solver is used.

Let an example,

$$\min_{x} f(x) \tag{3.15}$$

Linear programming (linprog) structure is,

$$[x, fval] = linprog(f, A, b, Aeq, beq, lb, ub, options)$$

Where,

f = Objective function

Linear inequality, $A * x \leq b$

Linear equality, Aeq * x = beq

$lb \leq x \leq ub$

lb= Lower bound

ub= Upper bound

Options structure created with optimset

x = Optimum value for objective function

fval = Minimum value at any feasible point

Procedure for Simulation:

- Define System Parameter
- Number of users as source and relay
- Calculate Path loss
- Define Constraint for power and bandwidth
- Define syntax for optimization
- Find weighing factor
- Calculate data rate for individual users and total data rate

Chapter 4

Simulation Results

In this chapter, simulation results compare among direct, cooperative and optimization. Also different relay techniques are used. Results are compared for various resource allocation techniques. For simulation MATLAB software is used.

4.1 Direct and Cooperative Communication

Here, Af relay technique is considered and for analysis experimental setup is shown in figure3.1,assumption is that relay is moving in horizontal direction between source and destination.

Simulation result shows in 4.1. From figure, it shows comparison between direct transmission and cooperative cooperation and with optimization. Distance between source to destination is 50m. Relay is moving towards the direction of destination from source. In results

System Parameter	Value
Distance	50 m
Noise power, No	10^{-11} w
Bandwidth, B	10^6 Hz
Initial distance, do	1 m
Path loss exponent, (a)	3
Total Transmitted Power (P)	2 w

Table I: System Parameter

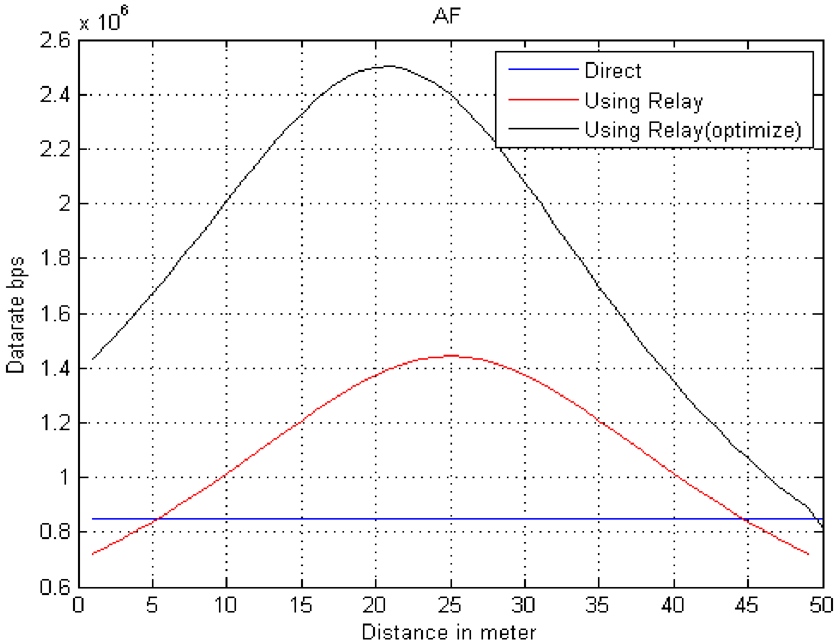

Figure 4.1: Comparison between direct, cooperative and using optimization

data rate at each and every distance of relay from source is indicated. In figure direct transmission means source send the data directly to the destination. Through relay means cooperative communication and data rate at the destination without diversity combining. Through relay optimize means use of optim tool for optimization.

4.2 Analysis of Different Resource Allocation Technique

For analysis AF and DF both relay technique is considered. As shown in figure3.2 both relay are moving towards destination starting from source 2 and source 3 respectively. Relays move 1 to 1000 meter and for various sources to destination distance is 1000, 1100, 1500, 1400 meter respectively. Here sources send the data to the destination using relay. For resource allocation, efficient, fair allocation and to provide best Qos, three types considered. Comparison of maximization of total data rate at the destination without diversity combining is given in table.

System Parameter	Value
Noise power, No	10^{-11} w
Total Bandwidth, B	$0.8 * 10^6$ Hz
Initial distance, do	10 m
Path loss exponent, (a)	3
Total Transmitted Power (P)	4 w

Table II: System Parameter

Let, first decode and forward relay technique.

4.2.1 DF Relay Technique

Simulation result is shown in figure 4.2.

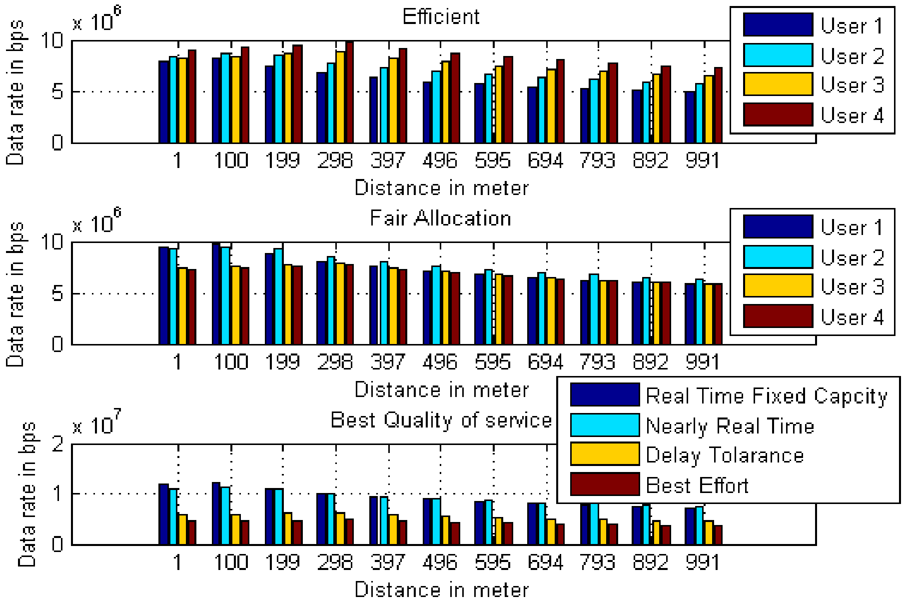

Figure 4.2: Comparison among different resource allocation type for users.

Sr No.	Distance in meter	Efficient $R * 10^6$	Fair $R * 10^6$	Best Qos $R * 10^6$
1	100	34.47	34.26	33.97
2	199	33.96	33.53	32.87
3	298	33.04	32.34	31.25
4	397	30.96	30.3	29.26
5	496	29.34	28.71	27.71
6	595	28.02	27.4	26.44
7	694	26.92	26.3	25.37
8	793	25.93	25.35	24.44
9	892	25.08	24.51	23.62
10	991	24.31	23.76	22.89

Table III: Analysis among different resource allocation type for total data rate of all users with respect to distance

Let, amplify and forward relay technique.

4.2.2 AF Relay Technique

Simulation result is shown in figure 4.3.

Sr No.	Distance in meter	Efficient $R * 10^6$	Fair $R * 10^6$	Best Qos $R * 10^6$
1	100	12.85	12.72	12.52
2	199	13.15	13.02	12.82
3	298	13.4	13.26	13.05
4	397	13.54	13.37	13.13
5	496	13.52	13.32	13.02
6	595	13.37	13.14	12.78
7	694	13.12	12.86	12.46
8	793	12.8	12.53	12.12
9	892	12.46	12.19	11.76
10	991	12.12	11.85	11.42

Table IV: Analysis among different resource allocation type for total data rate of all users with respect to distance

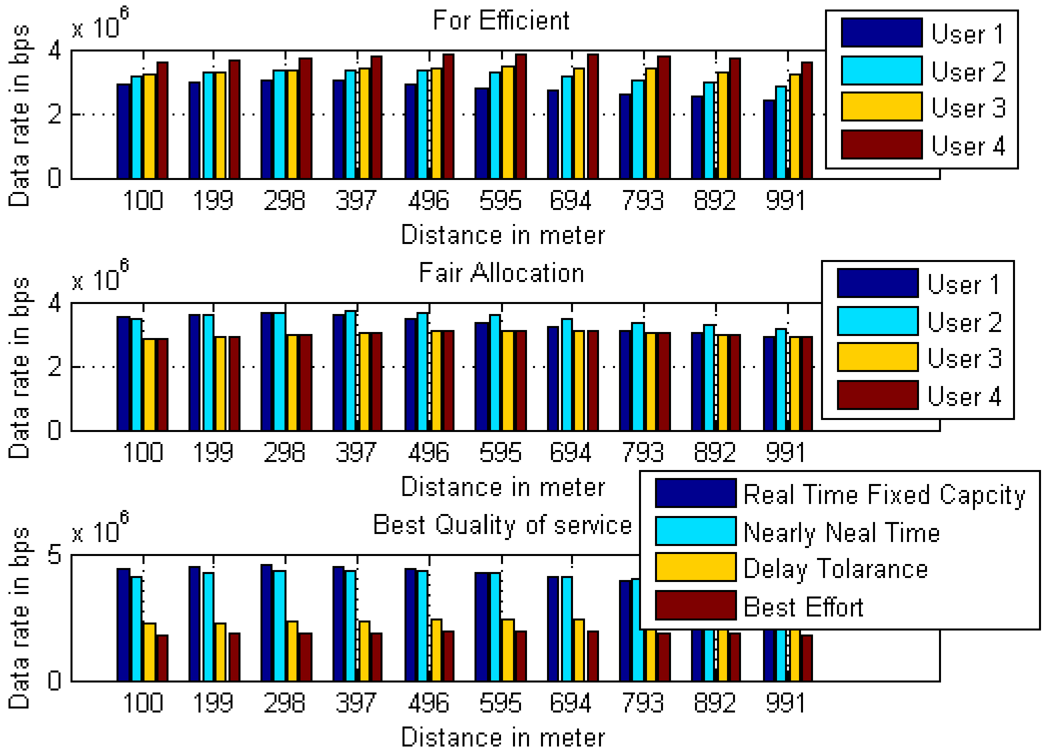

Figure 4.3: Comparison among different resource allocation type for users.

4.3 Utility

There are many users in a network and need of every user is different. For different channel link users are ready to pay depend upon their need and channel condition. So utility represents the degree of satisfaction of a user as a function of the transmission rate.

Utility for different application depend upon the data rate, Result shows for AF relay technique to provide best Qos.

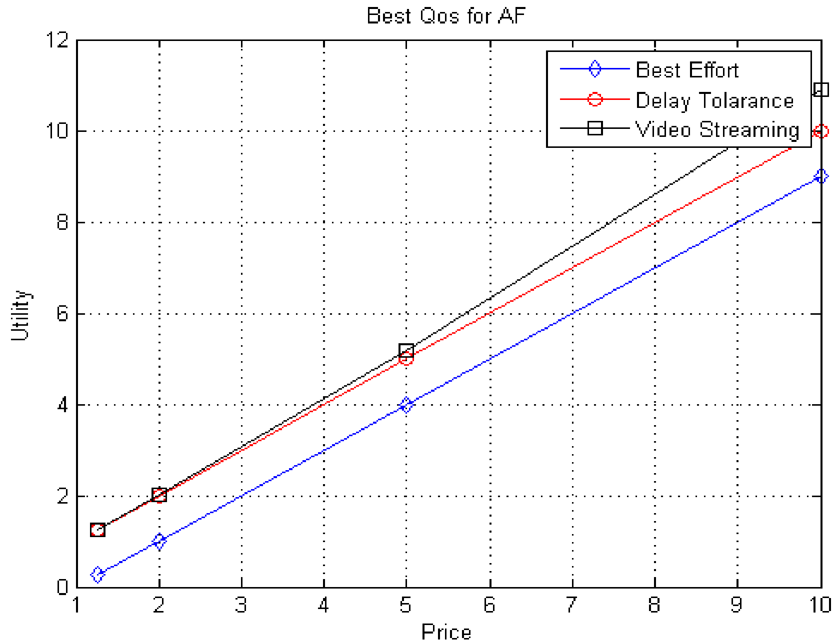

Figure 4.4: Comparison among users demand to provide best Qos

4.4 Fair allocation

As fair allocation is to get some minimum data rate. Here for fair allocation we consider two cases.

Relative fair allocation: using weighing factor to allocate resource whose path loss is more, more weighing factor and vice versa.

Absolute fair allocation: Also weighing factor can be defined by ratio of distance between two nodes to the initial distance.

Weighing factor, wf = $\frac{d}{do}$

Where, d = Distance between two nodes.

do = Initial distance.

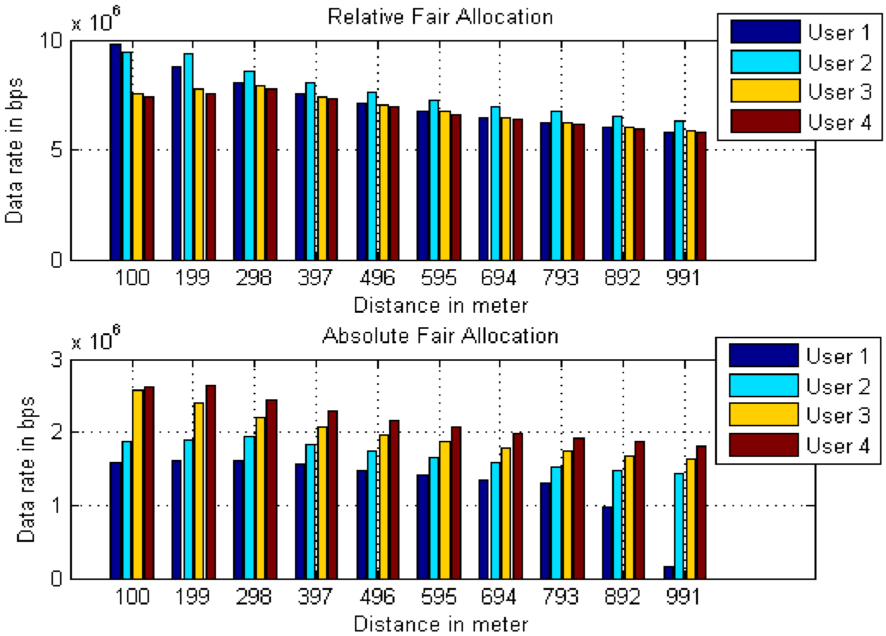

Figure 4.5: Relative and Absolute Fair Allocation for DF relay technique

Sr No.	Distance in meter	Relative $R * 10^6$	Absolute $R * 10^6$
1	100	34.26	8.6536
2	199	33.53	8.5362
3	298	32.34	8.1634
4	397	30.3	7.7416
5	496	28.71	7.3369
6	595	27.41	7.006
7	694	26.3	6.7263
8	793	25.35	6.4822
9	892	24.15	5.991
10	991	23.76	5.0265

Table V: Total Data rate of Relative and absolute fair allocation for DF

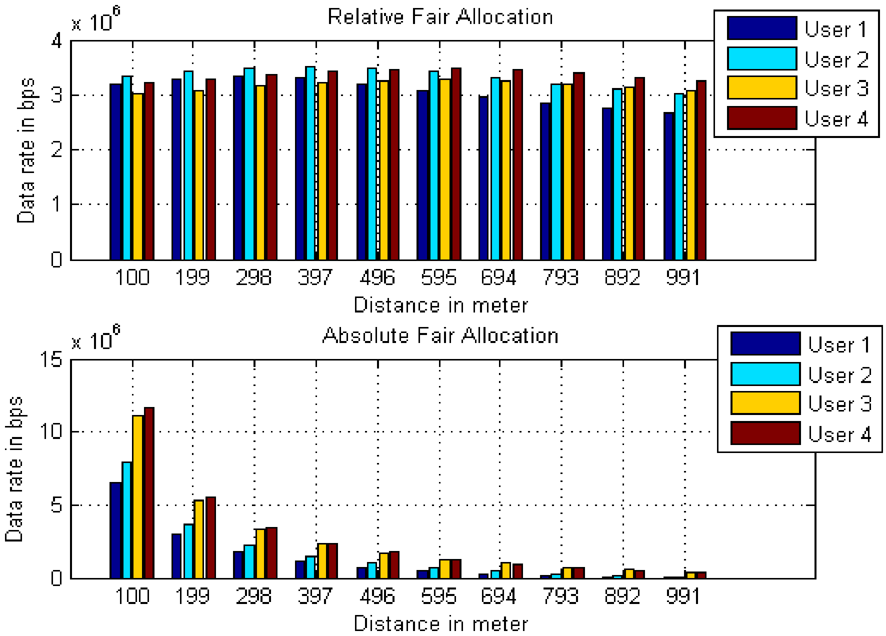

Figure 4.6: Relative and Absolute Fair Allocation for AF relay technique

Sr No.	Distance in meter	Relative $R * 10^6$	Absolute $R * 10^6$
1	100	12.78	37.27
2	199	13.09	17.53
3	298	13.33	10.82
4	397	13.46	7.37
5	496	13.42	5.22
6	595	13.25	3.78
7	694	12.99	2.73
8	793	12.67	1.94
9	892	12.33	1.33
10	991	11.91	0.87

Table VI: Total Data rate of Relative and absolute fair allocation for AF

Chapter 5

Conclusion and Future Work

5.1 Conclusion

In this project, first observed direct and cooperation scenario and then compare these result with using optimization. This result shows through relay optimization increase the data rate.

Now, for resource allocation, from the simulation result it is observed that the comparison among efficient, fair allocation and best Qos provide, efficient is better other than two, but when resources allocate fair then efficiency is reduced, so its tradeoff between fairly allocation resources and efficiency. Also DF relay technique gives better performance than AF relay technique.

For fair allocation to the users, between relative and absolute fair allocation, relative fair allocation gives better data rate then absolute fair allocation.

5.2 Future Work

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. Throughout this dissertation, the case of free space path loss model considered to highlight the data rate at the destination by AF and Df relay technique. Also three cases,efficient, fair and best Qos, considered for resource allocation. As from this reults data rate achieve but security issue, partner choice, relay is ready or not to help, these issues are remain to solve. Bargaining and game theory is one approach for partner choice.

Bibliography

[1] Bernard Skalar, Pabitra Kumar Ray, "*Digital Communications, Fundamentals and Application*", Pearson Education, 2009

[2] K. J. Rayliu, Ahmed K. Sadek, Andres Kwasinski, Weifeng Su, "*Cooperative Communications and Networking*", Cambridge University Press, 2009

[3] Y.-W. Peter Hong, Wan-Jen Huang, C.C. Jay Kuo," a " "*Cooperative Communications and Networking-Technologies and System Design*", Springer publication, 2010

[4] Mischa Dohler, Spain, "*Cooperative Communications Hardware, Channel & Phy*" John Wiley & Sons, Ltd, 2010.

[5] Miao Pan, Yuguang Fang, "*Bargaining Based Pairwise Cooperative Spectrum Sensing for Cognitive Radio Networks*", IEEE 2008

[6] Fang Liu, Rongsheng Dong, Jianming Liu, Xuliang Xu, "*A Reputation Mechanism to Stimulate Node Cooperation in Ad Hoc Networks*", IEEE computer society, 2009

[7] Jamal N. Al-Karaki, Ahmed E. Kamal, "*Stimulating Node Cooperation in Mobile Ad hoc Networks*"

[8] Liqiang Zhao, Le Guo, Guopeng Zhang, Hailin Zhang and Kun Yang,"*An Energy-efficient MAC Protocol for WSNs: Gametheoretic Constraint Optimization*", IEEE, 2008

[9] Xiaowen Gong, Sergiy A. Vorobyov, Chintha Tellmbura, "*Joint Bandwidth and Power Allocation Control in Wireless Multi-user Networks With and Without Relaying*", IEEE Transactions on Signal Processing, vol. 59, no. 4, April, 2011.

[10] Bing Xie,Wen'an Zhou, Chenxi Hao, Xiaoli Ai, Junde Song, "*A Novel Bargaining Based Relay Selection and power allication scheme for distributed cooperative communication networks*",IEEE vehicular conference, 2009

[11] G. Tychogiorgos, A. Gkelias and K. K. Leung, "*Utility-Proportional Fairness in Wireless Networks*".

[12] "*Optimization Toolbox Users Guide of MATLAB*"

[13] Bing Xie, Wenan Zhou, Chenxi Hao, "*A Novel Bargaining Based Power Allocation For Coordinated Multiple Point Transmission/Reception*", ICACT-2011

[14] LIU Wei, LUO Tao, YUE Guang-xin, "*Dynamic subcarrier and power allocation based on cooperative game theory in symmetric co-operative OFDMA networks*",Scince Direct, page 916, April, 2011

[15] Qian Cao, H. Vicky Zhao, Yindi Jing, "*Power Allocation and Pricing in Multi-User Relay Networks Using Stackelberg and Bargaining Games*", 15 Jan, 2012

[16] Naveen Shastry, Raviraj S., "*AdveStimulating Cooperative Diversity in Wireless Ad Hoc Networks through Pricing*", IEEE, 2006

[17] Darning Feng, Yanqin Zhu, Xizhao LUo, "*Cooperative Incentive Mechanism Based on Game Theory in MANET*", IEEE, 2009