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Performance Analysis of Cooperative Communication Protocols

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ABSTRACT

With the rapid growth of multimedia services, future generations of cellular communications require higher data rates and a more reliable transmission link while keeping satisfactory quality of service. In this respect, multiple input multiple-output (MIMO) antenna systems have been considered as an efficient approach to address these demands by offering significant multiplexing and diversity gains over single antenna systems without increasing requirements on radio resources such as bandwidth and power. Although MIMO systems can unfold their huge benefit in cellular base stations, they may face limitations when it comes to their deployment in mobile handsets.

To overcome this drawback, in cellular networks, relays (fixed or mobile terminals) can cooperate to improve the overall system performance. For example, once the transmission from a base station with multiple antennas is received by multiple nodes (fixed relays and/or mobiles); they can exchange information to enhance the quality of intended signals while suppressing interference. On the other hand, when a mobile user wants to communicate with the base station, but the link in between is too weak, and then the other nearby mobile users cooperates and shares their antennas to assist the direct communication. With this approach, the benefits of MIMO systems can be attained in a distributed fashion. Furthermore, cooperative communications can efficiently combat the severity of fading and shadowing effects through the assistance of relays. It has been shown that using relays the capacity and coverage of cellular networks can be extended without increasing the mobile transmit power or demanding for an extra bandwidth.

This paper is based on cooperative communications in wireless networks. We focus on Bit error rate (BER) performance analysis of cooperative communications with either an amplify-and-forward (AF) or decode-and-forward (DF) cooperation protocol using Matlab. We consider the single and multi relay scenario in these simulations.

Keywords: *MIMO, BER, Protocols*

1. INTRODUCTION

The success of IP technologies jointly with high data rate solutions at physical layer led to a rapid growth of telecommunications networks. However, radio resources are limited (and expensive) and one cannot infinitely increase the network capacity. The availability of vacant bandwidth is not expected to increase significantly. To date, the only way to get around this is by controlling the transmission power and increasing the spatial reuse of frequencies by cell spitting/sectoring. These were the driving principles behind the design of cellular networks of the past (Analog Mobile Phone system (AMPS), Global system for Mobile Communication (GSM) and also 3rd Generation (3G)). However, these methods incur huge installation and maintenance costs in 3G Universal Mobile Telecommunication system (UMTS) / Code Division Multiple Access (CDMA) 2000 and 4G Long Term Evolution (LTE) / worldwide interoperability for Microwave Access (WiMAX) networks where micro cells have a diameter of a few hundred meters. Further high license fee is an issue; there is thus a threat that high-quality wireless services may soon become an unaffordable luxury [1].

An extreme alternative are ad hoc networks, where packets are forwarded in a multi-hop fashion. In such networks, users cooperate to relay and process each other's information. Ad hoc networks are characterized by their low cost, rapid deployment and self-organization capability and face QOS, security and scalability problems. Consequently, standalone ad hoc networks are not promising for service commercialization [1].

A hybrid approach is thus beneficial which combines the aspects of both the cellular and Ad Hoc networks in order to construct a single network with high flexibility and improved network performance. In other words a cooperative communication can be a viable solution [1].

1.1 Industrial Motivation

Cooperative communications have been one of the most widely explored topics in communications over the past few years. The key idea is to have users cooperate in transmitting their messages to the destination instead of

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operating independently and competing among each other for channel resources as done in conventional cellular networks. This concept has modernized the design of wireless networks, allowing network operators to increase coverage, throughput, and transmission reliability [2].

The expected coverage and throughput benefits of a cooperative relaying approach with respect to conventional cellular networks are sufficiently large to attract industrial interest. From an economic point of view, the planning and optimization of BSs together with the leasing costs of their locations could be reduced through cooperation. They are potentially opening new business opportunities for network operators and service providers, allowing commercial service provisioning with broader coverage [1].

In recent years, cooperative relaying technologies have also made their way toward next generation wireless standards such as IEEE 802.16 (WiMAX) or LTE and have been incorporated into many modern wireless applications such as cognitive radio and secret communications. With its expanding scope of applications it is necessary for engineers to have a fundamental understanding of this concept [2].

However, the benefits of cooperative relaying are not only limited to cellular networks. The similar approach can also be used in Wireless local area Networks (WLAN) to boost the capacity and increase coverage, in vehicle-to-vehicle communication scenario, where vehicles cooperate to facilitate the relay, in wireless sensor networks for command and control etc [2].

The aim of this paper is to provide the basic concepts of cooperative communications and relay technology & analysis the Bit Error Rate (BER) performance of different cooperative communication protocols using MATLAB.

2. WIRELESS CHANNEL

A communication system consists of a transmitter and a receiver connected by a channel. The channel is the actual physical medium where a signal at the channel input will produce a corresponding channel output after suffering from various distortions. Examples of physical medium include telephone wire, coaxial cable, optical fiber, radio frequency, microwave and satellite. Different media have different signal propagation characteristics. In this chapter we focus on the wireless channel. Wireless channels make use of radio frequency part of electromagnetic spectrum to operate. Hence, they are also called radio frequency channel.

2.1 Key Characteristics

Wireless channel is characterized by its multipath, time varying and broadcast nature. These characteristics are described below [3].

a. Multipath Nature

Multipath refers to the situation that there are more than one propagation path between a transmitter and a receiver. Multipath are caused by the reflection, diffraction and scattering of the transmitted signal due to the surface of the Earth, buildings, foliage, street signs, lamp posts, peoples walking around etc. Fig-1 shows the illustration of multipath. The received signals form multi paths are superimposed with each other. Depending on the phase difference (or path difference) of the multipath, the superposition may be either constructive or destructive. When the superposition is constructive, the received signal will be strong. On the other hand, when the superposition is destructive, the received signal will be weak [3].

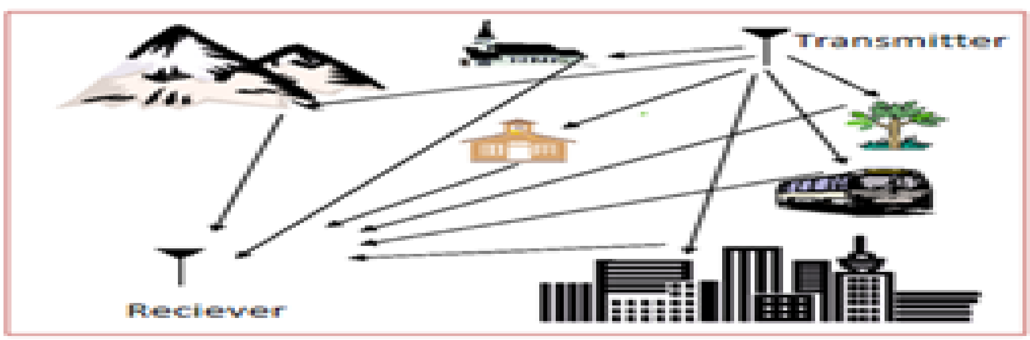

Fig 1: Multipath nature of the wireless channel

b. Time Varying Nature

Time variation of the wireless channel results from the mobility of the transmitter, the receiver or the environment (e.g. obstacle). Hence, the number of multipath, strength of multipath as well as delays of the multipath can be time varying.

c. Broadcast Nature

In a wireless medium when a node transmits, its transmission is overheard by other nodes within its range. But only the recipient node will respond to the transmission. Other nodes treat these overheard signals as interference and the system provides mechanisms to mitigate this interference.

2.2 Channel Models

The simplest wireless channel is the additive white Gaussian noise (AWGN) channel where the output signal from the channel is given by:

$$y = x + n \qquad (1)$$

Where x is the complex modulated signal transmitted through the channel and 'n' is the Additive Gaussian White Noise random variable with zero mean and variance σ2. In this channel, the received signal is composed of an undistorted transmit signal infected with channel noise. For AWGN the noise variance in terms of noise power spectral density (N0) is given as:

$$\sigma^2 = \frac{N_o}{2} \qquad (2)$$

For M-PSK modulation schemes including BPSK, the symbol energy is given by:

$$E_s = R_m \, R_c \, E_b \qquad (3)$$

Where E_s is Symbol energy per modulated bit (x), $R_m = \log_2 (M)$, For BPSK M=2, QPSK M=4, 16QAM M=16 & so on. R_c is the code rate of the system if a coding scheme is used. E_b is the Energy per information bit. Assuming E_s=1 for BPSK (Symbol energy normalized to 1) E_b/N_o can be represented as: (using above equations).

$$\frac{E_b}{N_o} = \frac{E_s}{R_m \, R_c \, E_b} \qquad (4)$$

From the above equation the noise variance for the given E_b/N_o can be calculated as:

$$\sigma^2 = \left(R_m \, R_c \, \frac{E_b}{N_o}\right)^{-1} \qquad (5)$$

For the channel model randn function in Matlab is used to generate the noise term. This function generates noise with unit variance and zero mean. In order to generate a noise with sigma σ for the given E_b/N_o ratio, use the above equation, find σ, and multiply the 'randn' generated noise with this sigma, add this final noise term with the transmitted signal to get the received signal [5]. AWGN channel is quite an accurate model for deep space communication between earth station and satellites.

On the other hand, for terrestrial wireless communication, the channel model is much more complicated due to the time varying nature as well as multipath nature of the wireless channel. This introduces distortions in the transmitted signal. To capture different types of distortions we use a three level model [2] & [3].

a. Large scale path loss model

The first level model is called large scale path loss model. The path loss model focuses on the study of the long term or large scale variations on the average received signal strength due to the variation of distance from the transmitter and the receiver. The path loss indicates how fast the received signal strength drops with respect to change in distance. The simplest path loss model is the free space path loss model where the average received signal strength is inversely proportional to the square of the distance e.g. the received signal strength is reduced by 4 times if we double the distance. But for terrestrial wireless communication the signal strength decreases more quickly. Here, the received signal strength is proportional to $1/d^4$ or $1/d^6$.

The path loss between transmitter and receiver is characterized by path loss exponent, which depends on environment. For free space or rural area its value is 2, for suburban from 2 to 3, for urban its value is about 4. The path loss due to different environments is shown in the Fig-2. The higher the path loss exponent is, the faster the signal strength drops with increasing the distance. In some more composite environments such as irregular terrain the path loss exponent is not deterministic. So some empirical model is used to model the path loss. Examples are Okumura model, Hata model and COST 231 extension to Hata model [3].

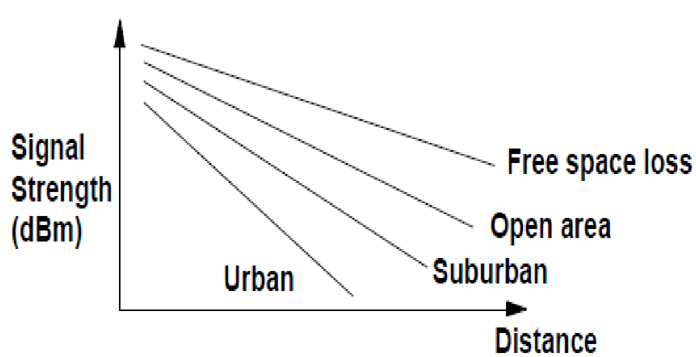

Fig 2: Illustration of path loss [22].

b. Medium Scale Shadowing Model

Shadowing model is the second level model, used to study the medium term variations in the received signal strength when the distance between the transmitter and receiver is fixed. For e.g. when a mobile station is circling around a base station. As the mobile moves, one expects some medium term fluctuations in the received signal strength. This signal variation is due to the variations in the terrain profile such as variation in the blockage due to trees, buildings, hills etc. This effect is called shadowing.

c. Small Scale Fading Model

The third level model which is used to quantify the variation of received signal strength is called small scale fading model. In small scale fading the signal strength fluctuates over 30dB in a very short time scale (i.e. mili or micro seconds). Fading is of two types, namely multipath fading and time varying fading, which are independent of each other.

C.1 Multipath Fading

To quantify the effects of multipath fading we use either the delay spread or coherence bandwidth. Delay spread is defined as the range of multipath components with significant power when an impulse is transmitted, as depicted in the fig-3. The graph of received power with delay is called power delay profile (PDP) and is used to measure the delay spread. It is measured in micro seconds. Typically, the delay spread in indoor environment is smaller than the outdoor environment because the multi paths are more contained in the indoor environment.

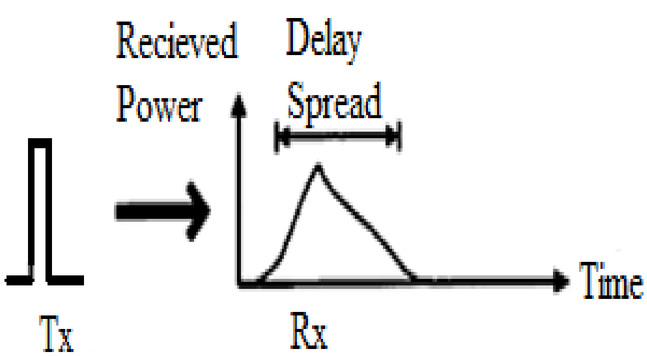

Fig 3: Delay spread [3]

On the other hand, to quantify the multipath fading, an equivalent parameter, called coherence bandwidth, can be used. It is defined as the minimum frequency separation at the transmitter such that uncorrelated fading occur at the receiver. Mathematically,

$$|f1 - f2| > B_c \tag{6}$$

Where B_c is the coherence band width. This is the bandwidth over which the channel transfer function remains virtually constant. It is related to delay spread as follows:

$$B_c \approx \frac{1}{\sigma_\tau} \tag{7}$$

C.1.1 Flat fading vs. Frequency selective fading

Based on the delay spread and the transmitted symbol duration, or equivalently the coherence bandwidth and the transmitted signal bandwidth, the multipath fading can be classified as frequency flat fading or frequency selective fading. A fading channel is said to be frequency flat if $\sigma_\tau < T_s$ or equivalently $B_c > W_{tx}$. Otherwise the fading channel is said to be frequency selective.

When the transmit signal experience flat fading the received signal consists of a single pulse, which is composed of superposition of multipath signals with delays much smaller than the symbol duration, hence the multipath are irresolvable. The effect of flat fading is the flattening of the BER curve.

On the other hand, when a transmit signal experience frequency selective fading, the received signal consists of multipath with delays greater than symbol duration. Hence, the received signal consists of pulses at resolvable delays. The effect of frequency selective fading is flattening of BER curve and mixing of symbols (ISI).

C.1.2 Time Varying Fading

To characterize time varying fading effect we can use either the Doppler spread or coherence time. Doppler spread refers to the spread of frequency introduced by the fading channel when we transmit a single narrow pulse as shown in the fig-4 below:

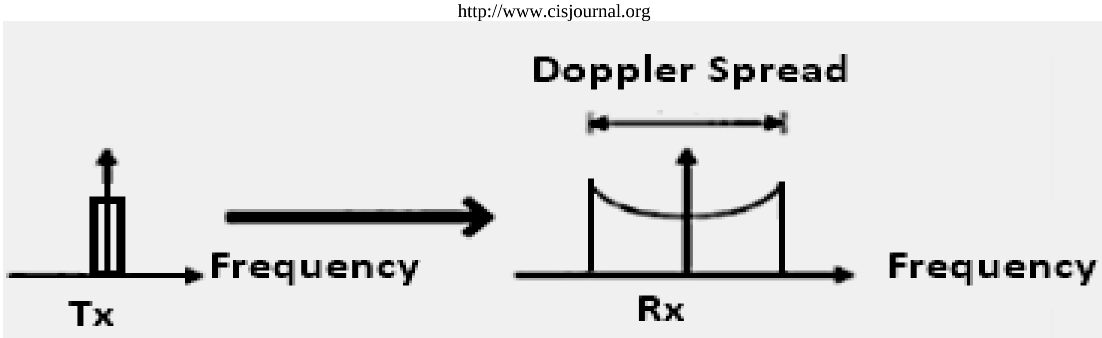

Fig 4: Doppler spread [3]

The spread in the frequency is due to the mobility between transmitter and the receiver or the mobility of the surrounding obstacles. The maximum Doppler spread is given by:

$$f_d = \frac{v}{\lambda} \quad (8)$$

On the other hand, coherence time is defined as the minimum time separation at the transmitter in order to have uncorrelated fading at the receiver. Mathematically,

$$|t1 - t2| > T_c \quad (9)$$

Coherence time is a measure of the time duration over which the channel impulse response is invariant, and quantifies the similarity of the channel response at different times.

$$T_c \approx \frac{1}{f_d} \quad (10)$$

C.1.2.1 Fast fading vs. slow fading

Similarly, based on the Doppler spread and the transmitted bandwidth or equivalently the coherence time and the symbol duration, the time varying fading can be classified as fast fading or slow fading. A fading channel is called a fast fading channel if $T_s > T_c$ or equivalently $W_{tx} < f_d$. Otherwise the fading channel is called as slow fading. In fast fading the channel impulse response changes rapidly within the symbol duration whereas in slow fading it changes slowly. The Complete classification of fading channels is illustrated in the Fig-5.

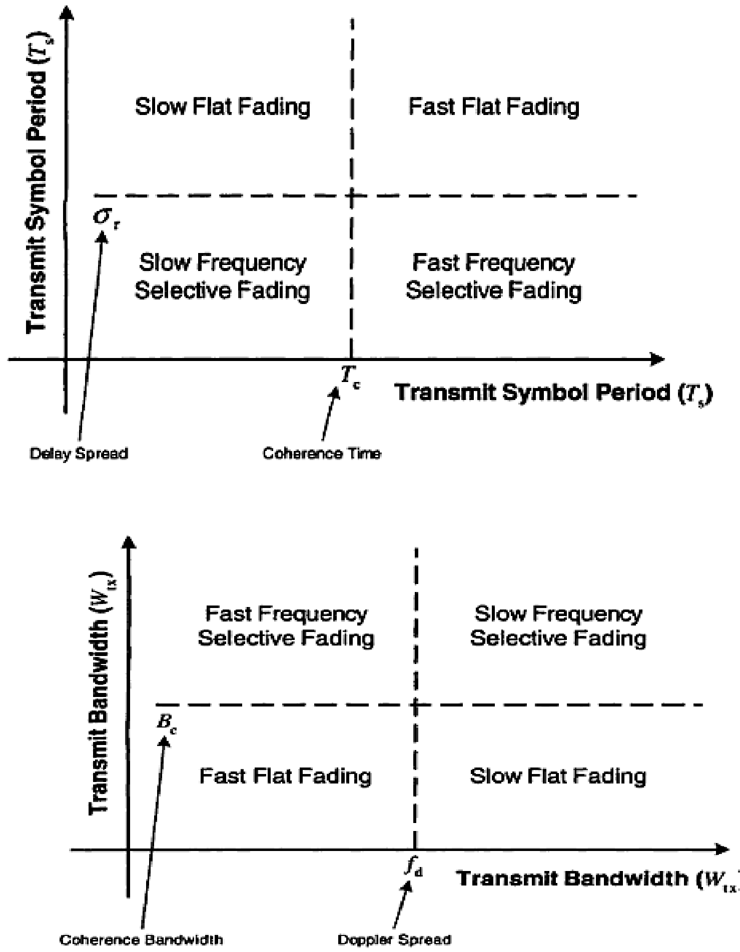

Fig 5: Classification of fading channels [3]

2.3 Rayleigh Fading Vs Rician Fading

Rayleigh fading is a type of fading that occurs when there is large number of reflections present. The Rayleigh fading uses a statistical approach to analyze the propagation, and can be used in a number of environments. It operates best under conditions when there is no dominant signal (e.g. direct line of sight signal), and in dense urban

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environments. Rayleigh fading has a fading envelope in the form of the Rayleigh Probability Density Function (PDF).

The Rician fading is similar to Rayleigh fading, except that in Rician fading a strong dominant component is present. This dominant component can be the line-of-sight signal. Besides the dominant component, there is large number of reflected and scattered waves. This fading characteristic exhibits a Rician PDF (Probability Density Function) [6].

3. OVERVIEW ON COOPERATIVE COMMUNICATION

3.1 Wireless Communication and MIMO Systems

Wireless communications has grown successfully over the last two decades and is expected to continue in the future. Today, there is an increasing demand for high data rates in order to support high speed interactive internet services and advanced multimedia applications such as mobile TV, online gaming etc. This trend is enormously evolving into the 4G systems.

However, the transmission over wireless channel of high rate (i.e. bandwidth) demanding services faces fundamental limitations due to impairments inflicted by the wireless channel due to path loss, shadowing and fading effects as explained in chapter 2. These impairments can be compensated by various ways such as by increasing transmit power, bandwidth, and/or applying powerful error control coding (ECC). However, power and bandwidth are very scarce and expensive radio resources while ECC yields reduced transmission rate. Hence, acquiring a high data rate together with reliable transmission over error-prone wireless channels is a major challenge for a wireless system designer.

Another way to cope with the impairments offered by the wireless channel is the use of MIMO (multiple-input multiple-output) systems. In MIMO systems, multiple antennas are used at the transceiver. This arrangement can significantly increase the data rate and reliability of the wireless link. MIMO systems use either VBLAST (Vertical Bell Laboratories Layered Space-Time) or DBLAST (Diagonal Bell Labs Layered Space-Time) algorithm. Using VBLAST spectral efficiency of up to 42 bps/Hz can be achieved and DBLAST gives spectral efficiency of up to 30bps/Hz, which as compared to 3bps/Hz of a traditional cellular system is a remarkable achievement. However, using multiple co-located antennas causes degradation in the system QOS due to correlation between them. Also due to size, cost, or hardware limitations, a small handheld wireless device may not be able to support multiple antennas [9].

To overcome the above drawback, an innovative approach known as cooperative communication has been suggested to exploit MIMO's benefit in a distributed manner. Such a technique is also called a virtual MIMO, since it allows single antenna mobile terminals to reap some of the benefits of MIMO systems. This concept is illustrated in Fig-6 below [8] & [9]:

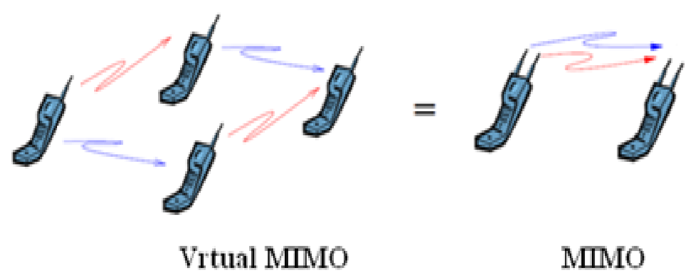

Fig 6: Illustration of MIMO and virtual MIMO systems [8]

3.2 Working Principle

The idea of cooperation was first presented by van der Meulen in 1971, which established the foundations of the relay channel. Cooperative communication takes advantage of the broadcast nature of the wireless medium where the neighboring nodes overhear the source's signals and relay the information to the destination. Thus, creating a virtual antenna array through cooperating nodes [2].

3.3 Cooperative Relaying System Model

Cooperative relaying techniques can be realized in systems with either single relay or multiple relays per user. These system models are illustrated below [2].

a. Single Relay System Model

The basic model for cooperative system is a three terminal system model with on source, one relay and one destination as shown in the fig-7. Suppose terminal 1 (source) and terminal 3 (destination) want to communicate with each other but the link between is too weak and there is another terminal 2 (relay) which resides in between terminals 1 and 3. However, the link from terminal 2 to both sides is fairly good so it will act as a relay to assist the direct communication. Terminal 2 receives the data from the terminal 1, performs some signal processing and then forwards that processed data to the terminal 3. The terminals may interchange their roles as source, relay and destination at different instants in time.

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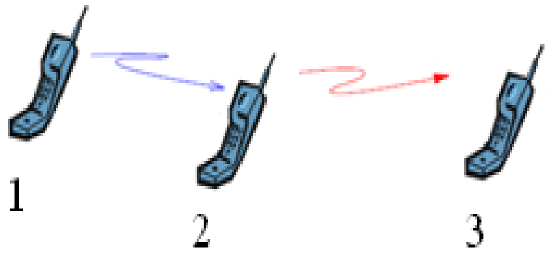

Fig 7: Cooperative system model with single relay [8]

b. Multi Relay System Model

However, in practical systems there are multiple sources, all transmitting at the same time to the multiple destinations? This requires multiple relays in the system as depicted in Fig-8. In this case relays form a virtual antenna array and exploit some of the benefits of MIMO systems. But this scenario causes problems in resource allocation strategies, since multiple relays have to be allocated resources to assist the cooperation between them. Thus, multiple access schemes must be devised to separate their signals in time (TDMA), frequency (FDMA), code (CDMA) or space (SDMA). In TDMA/FDMA systems, sources transmit over orthogonal time or frequency channels, where radio resources must be properly allocated to fully exploit the advantages of cooperation. In CDMA or SDMA systems, users transmit simultaneously over different code or spatial dimensions.

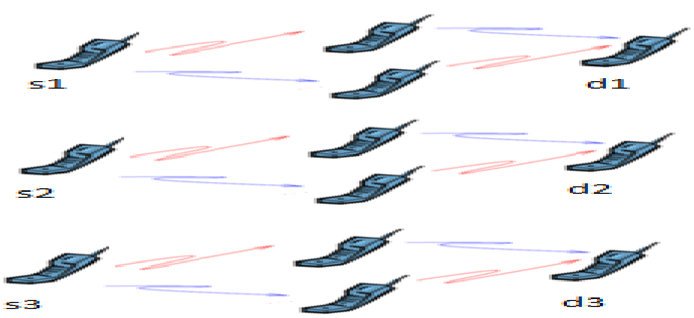

Fig 8: Cooperative system model with multiple relays [8]

3.4 Gains Due To Cooperation

Cooperative communications yields several gains. Three of the most important gains are given below [10]:

a. Path Loss Gain

Path loss gain is achieved by splitting the propagation path into two or more parts.

Because the aggregated path loss of the split path is less than the path loss of the full path. The path loss and hence the signal-to-noise

$$SNR \propto \frac{1}{d^n} \qquad (11)$$

Splitting, for example, the communication path between source and destination into two equal distances and allocating to each part half of the power, the gain w.r.t. direct communication assuming a path loss coefficient of n = 4 is quantified as $10 \log_{10} 16 = 12$ dB power saving. This is a significant gain and one of the main incentives for using cooperative techniques.

b. Diversity Gain

Providing multiple independent copies of the same information yields diversity gains. A single relay provides a single independent copy of the same information in addition to the information from the direct path. By using several relays gives multiple copies in parallel. Diversity gains improve the performance of the system because as the number of copies increases the probability of all of them being illegible decreases, in other words the probability of reception increases.

c. Multiplexing Gain

The data rate and the SNR are related as follows

$$R = r \log_2 SNR + const \qquad (12)$$

Where r is the multiplexing gain and refers to the number of independent channels over which different information can be sent. For instance, if a source node possesses one transmit and a destination node two receive antennas or vice versa, they can communicate at a multiplexing gain of one, since only one independent channel can be provided. Using a relay in addition to the direct link creates a second channel, hence doubling the multiplexing gain and thus the communication rate, assuming the SNR is kept constant.

3.5 Multiple Access and Other Practical Issues

Cooperative communication requires that the base station separately receive the original and relayed data. This is accomplished by transmitting the two parts orthogonally so that they can be separated. The most common method is separation in time, i.e. the source's data and relayed data are transmitted in non overlapping time intervals. It is also possible to achieve separation in frequency by transmitting the source's and relayed data on separate frequencies. In cellular systems, even in time-division multiple accesses (TDMA), the uplink and downlink transmissions are

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performed on separate frequency bands (FDD). Ordinary mobiles receive only in the downlink band, but cooperative mobiles need to also receive in the uplink band, thus requiring additional input filters and frequency conversion. Another technological issue is transmit and receive requirements on the mobiles. In TDMA and FDMA systems this is generally not a problem, since in TDMA the uplink transmissions by definition are non-overlapping in time and in FDMA the uplink transmissions are carried on different frequencies. However, in other multiple access systems, such as CDMA, the mobiles may be required to transmit and receive at the same time. But CDMA systems are actually hybrid, with more than one frequency band allocated to the uplink channel. Then the base station may require that cooperating mobiles reside on separate bands [7].

Furthermore, since cooperation is conditional, the base station needs to know whether the users have cooperated or not. More precisely, the base station needs to know whose information bits each user is transmitting in the second frame. A simple solution is that the base station simply decodes according to each of the possibilities in succession until successful decoding results. This strategy maintains the overall system performance and rate at the cost of some added complexity at the base station.

Other practical issue with cooperative communication is that the relays must have sufficient energy and bandwidth resources for all users. If this is not the case, many multiuser problems may arise in both the physical and higher order layers. From the physical layer perspective, this result in multiple access interference (MAI) that may eventually degrades the BER performance and cause the diversity gains to diminish. Moreover, with limited energy and bandwidth resources at the relays, efficient resource allocation policies must be devised to ensure high performance gains for all users. From the medium access control (MAC) layer perspective, random access protocols must be developed to help resolve contention among those competing for the cooperative channel.

For cooperative communication technology to be fully deployed in modern communication systems, many higher layer issues must be resolved. The most important among all is the issue of resource allocation between the source-relay, relay-destination, and source-destination links. Moreover, user mobility is also a major issue as cooperative links may not be stable if cooperating users/relays are mobile and handoff between relay stations may be frequent. Other issues such as buffer management and cooperative queuing must be addressed to determine how the relay packets should be treated at each relay or cooperative user. Security and authentication mechanisms must be developed to combat the effect of malicious or unauthorized relays [2].

4. COOPERATIVE RELAYING TECHNIQUES

4.1 Introduction

In this section, we will discuss Different Cooperative Protocols or Transmissions Techniques used in Cooperative Communication. Cooperative communications protocols can be generally categorized into fixed relaying schemes and adaptive relaying schemes. In this chapter we describe both of these schemes & consider single relay as well as multi relay scenario.

4.2 Cooperation Protocols

A cooperation strategy is modeled into two orthogonal phases, either in TDMA or FDMA, to avoid interference between the two phases:
In phase 1, source sends (broadcast) information to its destination, and the information is also received by the relay (due to broadcast) at the same time as it shown in figure below.

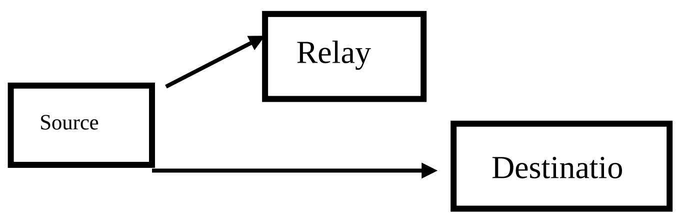

Fig 9: Phase 1

In phase 2, the relay can help the source by forwarding or retransmitting the Information to the destination as it shown in figure below.

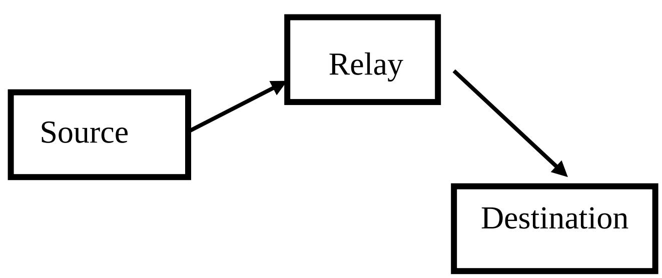

Fig 10: Phase 1

Fig- 11 below depicts a general relay channel, where the source transmits with power P1 and the relay transmits with power P2. In this paper, we will consider the special case where the source and the relay transmit with

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equal power P. Optimal power allocation is a vast topic so can be Consider for future work.

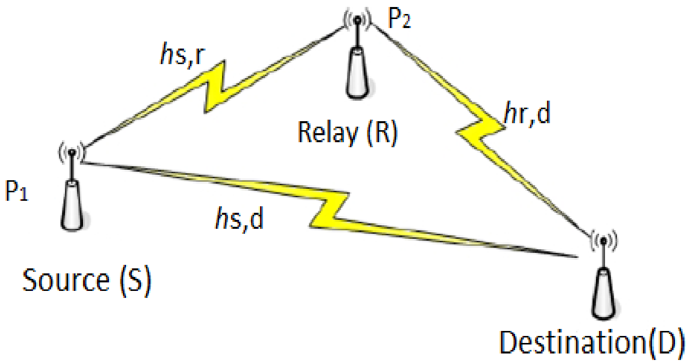

Fig 11: Simplified Cooperation Model [21]

In phase 1, the source broadcasts its information to both the destination and the relay. The received signals Y_{sd} and Y_{sr} at the destination and the relay, respectively, can be written as

$$Y_{sd} = \sqrt{P} h_{sd} x + n_{sd} \quad (13)$$

$$Y_{sr} = \sqrt{P} h_{sr} x + n_{sr} \quad (14)$$

Where P is the transmitted power at the source, x is the transmitted information symbol, and n_{sd} and n_{sr} are additive noise. In (13) and (14), h_{sd} and h_{sr} are the channel fades between the source and the relay and destination, respectively, and are modeled as Rayleigh flat fading channels. Rayleigh flat fading channel can be mathematically modeled as complex Gaussian random variable. Written as z = x + jy where real and imaginary parts are zero mean independent and identically distributed (IID) Gaussian random variables. The noise terms n_{sd} and n_{sr} are modeled as zero-mean complex Gaussian random variables with variance No.

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

$$Y_{rd} = h_{rd}\, q(Y_{sr}) + n_{rd} \quad (15)$$

Where the function q(·) depends on which processing is implemented at the relay node. [18]

4.3 Fixed Cooperation Strategies

In fixed relaying, the channel resources are divided between the source and the relay in a fixed (deterministic) manner. The processing at the relay differs according to the employed protocols. The most common techniques are the fixed AF relaying protocol and the fixed relaying DF protocol.[15] & [17]

a. Fixed Amplify & Forward (Single Relay)

In a fixed AF relaying protocol, which is often simply called an AF protocol, the relay Scales the received version and transmits an amplified version of it to the destination. The amplify-and-forward scheme is presented in Fig-12

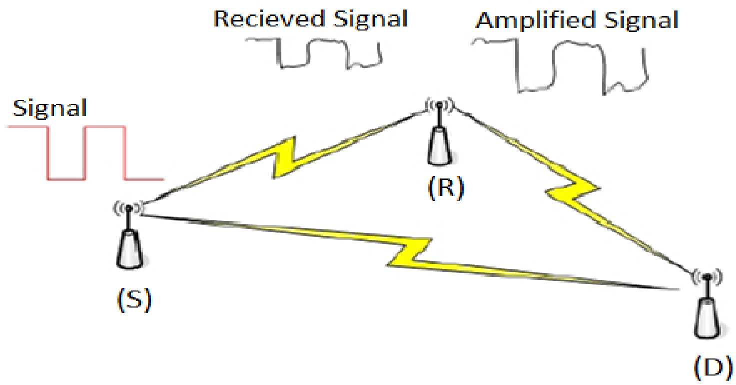

Fig 12: Amplify and Forward System Model [21]

The amplify-and-forward relay channel can be modeled as follows. The signal transmitted from the source x is received at both the relay and destination as

$$Y_{sr} = \sqrt{P} h_{sr} x + n_{sr} \text{ and } Y_{sd} = \sqrt{P} h_{sd} x + n_{sd} \quad (16)$$

Where h_{sr} and h_{sd} are the channel fades between the source and the relay and destination, respectively. The terms n_{sr} and n_{sd} denote the additive white Gaussian noise with zero-mean and variance No. In this protocol, the relay amplifies the signal from the source and forwards it to the destination ideally to equalize the effect of the channel fade between the source and the relay. The relay does that by simply scaling the received signal by a factor that is inversely proportional to the received power, which is denoted by

$$\beta = \frac{\sqrt{P}}{\sqrt{P|h_{s,r}|^2 + N_o}} \quad (17)$$

The signal transmitted from the relay is thus given by β Y_{sr} and has power P equal to the power of the signal transmitted from the source. In phase 2 the relay amplifies the received signal and forwards it to the destination with transmitted power P. The received signal at the destination in phase 2 according to (17) is given as

$$Y_{rd} = \frac{\sqrt{P}}{\sqrt{P|h_{s,r}|^2 + N_o}} h_{rd} Y_{sr} + n_{rd} \quad (18)$$

Here h_{rd} is the channel coefficient from relay to the destination and n_{rd} is an additive noise. More specifically, the received signal Y_{rd} in this case is

$$y_{r,d} = \frac{\sqrt{P}}{\sqrt{P|h_{s,r}|^2+N_o}} \sqrt{p}\; h_{r,d} h_{s,r} x + n'_{r,d} \tag{19}$$

Where

$$n'_{r,d} = \frac{\sqrt{P}}{\sqrt{P|h_{s,r}|^2+N_o}} h_{r,d}\, n_{s,r} + n_{r,d} \tag{20}$$

Assume that the noise terms n_{sr} and n_{rd} are independent, then the equivalent noise n'_{rd} is a zero-mean, complex Gaussian random variable with variance:

$$\tilde{N}_o = \left(\frac{P|h_{r,d}|^2}{P|h_{s,r}|^2+N_o} + 1\right) N_o \tag{21}$$

The destination receives two copies from the signal x through the source link and relay link, there are different techniques to combine the two signals. The optimal technique that maximizes the overall signal-to-noise ratio is the maximal ratio combiner (MRC). Note that MRC combining requires a coherent detector that has knowledge of all channel coefficients. With knowledge of the channel coefficients h_{sd}, h_{sr} and h_{rd} the output of the MRC detector at the destination can be written as

$$Y = a1\, Y_{sd} + a2\, Y_{rd} \tag{22}$$

The combining factors a1 and a2 should be designed to maximize the combined SNR. An easier way to design them is be resorting to signal space and detection theory principles. Since, the AWGN noise terms span the whole space, to minimize the noise effects the detector should project the received signals Y_{sd} and Y_{sr} to the desired signal spaces. Hence, Y_{sd} and Y_{rd} should be projected along the directions of h_{sd} and h_{rd} h_{sr}, respectively, after normalizing the noise variance terms in both received signals. Therefore, a1 and a2 are given by [18]

$$a_1 = \frac{\sqrt{P}\, h^*_{s,d}}{N_o} \quad \& \quad a_2 = \frac{\sqrt{\frac{P}{P|h_{s,r}|^2+N_o}}\,\sqrt{P}\, h^*_{s,r} h^*_{r,d}}{\left(\frac{P|h_{r,d}|^2}{P|h_{s,r}|^2+N_o}+1\right) N_o}$$

b. Fixed Amplify & Forward (Multi Relay)

We now focus on a multi-node amplify-and-forward strategy. An amplify-and-forward protocol does not suffer from the error propagation problem because the relays do not perform any hard-decision operation on the received signal. We first describe the multi-node amplify-and-forward protocol in detail and then analyze its two relaying strategies. In the first scenario, each relay forwards only the source's signal to the destination, while in the second scenario each relay forwards a combined signal from the source and previous relays. The multi-node amplify-and-forward system model is shown in Fig-13

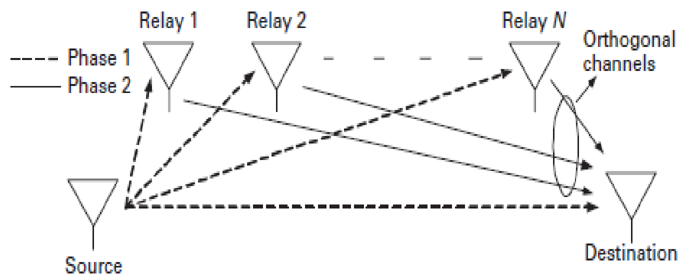

Fig 13: Multi Node Amplify and Forward System Model [18]

B.1 Source-Only Amplify-And-Forward Relaying

In a source-only multi-node amplify-and-forward relaying strategy, i.e. each relay forwards only the source's signal to the destination, cooperation is done in two phases. In phase 1, the source broadcasts its information to the destination and N relay nodes. The received signals Y_{sd} and Y_{sri} at the destination and the i^{th} relay can be written, respectively, as

$$Y_{sd} = \sqrt{Po}\, h_{sd}\, x + n_{sd} \tag{23}$$

$$Y_{s,ri} = \sqrt{Po}\, h_{sri}\, x + n_{sri} \tag{24}$$

for i = 1, 2, . . . , N, in which Po is the transmitted source power, n_{sd} and $n_{s,ri}$ denote the additive white Gaussian noise at the destination and the i^{th} relay, respectively, and h_{sd} and h_{sri} are the channel coefficients from the source to the destination and the i^{th} relay node, respectively. Each relay amplifies the received signal from the source and re-transmits it to the destination. The received signal at the destination node in phase2 due to the i^{th} relay transmission is given as

$$Y_{ri,d} = \frac{\sqrt{P_i}}{\sqrt{P_o|h_{s,ri}|^2+N_o}}\, h_{ri,d}\, Y_{s,ri} + n_{ri,d} \tag{25}$$

Here Pi is the i^{th} relay node power. The channel coefficients h_{sd} , $h_{s,ri}$, and $h_{ri,d}$ are modeled as zero-mean, complex Gaussian random variables, at the receiving nodes but not at the transmitting nodes. The noise terms are modeled as zero-mean, complex Gaussian random variables with variance N0. Jointly combining the signal received from the source in phase 1 and those from the relays in phase 2, the destination detects the transmitted symbols by use of maximum-ratio combining.

With the knowledge of the channel state information, the output of the MRC detector at the destination can be written as [18]

$$Y_d = \alpha s\, Ysd + \sum_{i=1}^{N} \alpha i\, Yri,d \tag{26}$$

Where

$$\alpha_s = \frac{\sqrt{Po}\,h^*_{sd}}{No} \quad \text{and} \quad \alpha_i = \frac{\sqrt{\frac{P_oP_i}{P_o|h_{s,ri}|^2+N_o}}\, h^*_{s,ri}\, h^*_{ri,d}}{\left(\frac{P_i|h_{ri,d}|^2}{P_o|h_{s,ri}|^2+N_o}+1\right)N_o}$$

B.2 Multi Relay Cooperation-Based Amplify-And-Forward Relaying

In this subsection we describe MRC-based multi-node amplify-and-forward relaying strategy. For simplicity of presentation, we will focus on the scenario of two relay nodes, but the extension to N relay nodes is straightforward. With two relaying nodes, the protocol is implemented in three phases as follows:

In phase 1, the source broadcasts its information to the destination and the two relay nodes.

In phase 2, the first relay helps the source by amplifying the source signal and sending it to the destination and the second relay.

In phase 3, the second relay applies an MRC detector on the two received signals from the previous two phases and forwards the amplified MRC signal to the destination.

In general, we have N + 1 phases for a system with N relay nodes, in which each relay applies an MRC detector on the signals that it receives from the source and all previous relays. The MRC detector has the advantage of maximizing the SNR at the output of the detector under the condition that the noise components of the combined signals are uncorrelated.

Let us focus on the two-relay scenario. The received signals at the destination and the relays in phase 1 are the same as those in the source-only amplify-and-forward scenario.

In phase 2, the received signal at the destination due to the first relay transmission is also the same as in the source-only scenario. However, the received signal at the second relay due to the first relay transmission is given as

$$y_{r1,r2} = \frac{\sqrt{P1}}{\sqrt{P_o|h_{s,r1}|^2+N_o}}\, h_{r1,r2}\, y_{s,r1} + n_{r1,r2} \tag{27}$$

Here the inter-relay channel, $h_{r1,r2}$, is modeled as a zero-mean, complex Gaussian random. In phase 3, the second relay applies an MRC detector on the signals received in phases 1 and 2, and the output of the MRC detector can be written as

$$\tilde{y} = \tilde{\alpha}_s\, y_{s,r2} + \tilde{\alpha}_1\, y_{r1,r2} \tag{28}$$

Where

$$\tilde{\alpha}1 = \frac{\sqrt{\frac{P_oP_1}{P_o|h_{s,r1}|^2+N_o}}\, h^*_{s,r1}\, h^*_{r1,r2}}{\left(\frac{P_1|h_{r1,r2}|^2}{P_o|h_{s,r1}|^2+N_o}+1\right)N_o}$$

and $\tilde{\alpha}s = \frac{\sqrt{Po}\,h^*_{s,r2}}{No}$

The received signal at the destination in phase 3 is given by

$$y_{r2,d} = \sqrt{P_2}\, h_{r2,d}\, \frac{\tilde{y}}{\sqrt{K^2+K}} + n_{r2,d} \tag{29}$$

Where

$$K = \frac{\frac{P_oP_1}{P_o|h_{s,r1}|^2+N_o}\, |h_{s,r1}|^2 |h_{r1,r2}|^2}{\left(\frac{P_1|h_{r1,r2}|^2}{P_o|h_{s,r1}|^2+N_o}+1\right)N_o} + \frac{P_o|h_{s,r2}|^2}{N_o}$$

Finally, the destination applies an MRC detector on the signals that it receives from all phases and jointly detects the information from the source. [16]

c. Fixed Decode and Forward (Single Relay)

Another processing possibility at the relay node is for the relay to decode the received signal, re-encode it, and then retransmit it to the receiver. The decode-and-forward scheme is presented in Fig-14. This kind of relaying is termed as a fixed decode-and-forward (DF) scheme, which is often simply called a DF scheme without the confusion from the selective DF relaying scheme. If the decoded signal at the relay is denoted by x', the transmitted signal from the relay can be denoted by $\sqrt{P}$ x', given that x' has unit variance.

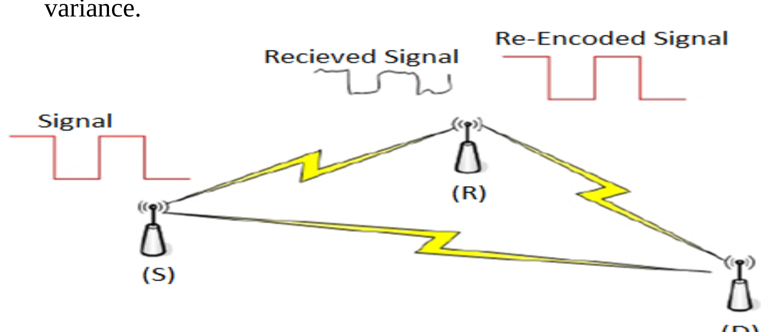

Fig 14: Decode and Forward System Model [18]

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Note that the decoded signal at the relay may be incorrect. If an incorrect signal is forwarded to the destination, the decoding at the destination is meaningless. It is clear that for such a scheme the diversity achieved is only one, because the performance of the system is limited by the worst link from the source–relay and source–destination. Although fixed DF relaying has the advantage over AF relaying in reducing the effects of additive noise at the relay, it entails the possibility of forwarding erroneously detected signals to the destination, causing error propagation that can diminish the performance of the system. The mutual information between the source and the destination is limited by the mutual information of the weakest link between the source–relay and the combined channel from the source–destination and relay–destination. The received signal at the destination in Phase 2 in this case can be modeled as

$$y_{r,d} = \sqrt{\tilde{P}_2}\, h_{r,d}\, x + \eta_{r,d} \qquad (30)$$

With knowledge of the channel coefficients h_{sd} (between the source and the destination) and h_{rd} (between the relay and the destination), the destination detects the transmitted symbols by jointly combining the received signal Y_{sd} (13) from the source and Y_{rd} (31) from the relay. The combined signal at the MRC detector can be written as

$$Y = a1\ Y_{sd} + a2\ Y_{rd} \qquad (31)$$

In which the factors a1 and a2 are determined such that the SNR of the MRC output is maximized, they can be specified as [18]

$$a_1 = \sqrt{P_1}\, {h^*_{s,d}}/{N_o} \quad \& \quad a_2 = \sqrt{\tilde{P}_2}\, {h^*_{r,d}}/{N_o}$$

d. Fixed Decode and Forward (Multi Relay)

We consider an arbitrary N-relay (2 Relay For Simulation Purpose) wireless network, where information is to be transmitted from a source to a destination. Due to the broadcast nature of the wireless channel, some relays can overhear the transmitted information and thus can cooperate with the source to send its data. The wireless link between any two nodes in the network is modeled as a Rayleigh fading channel with additive white Gaussian noise (AWGN). The channel fades for different links are assumed to be statistically independent. This is a reasonable assumption as the relays are usually spatially well separated. The additive noise at all receiving terminals is modeled as zero-mean, complex Gaussian random variables with variance N0. For medium access, the relays are assumed to transmit over orthogonal channels, thus no inter-relay interference is considered in the signal model.

The cooperation strategy we are considering employs a decode-and-forward protocol at the relaying nodes. In which each relay can combine the signal received from the source along with one or more of the signals transmitted by previous relays, decode it and then retransmit it to the receiver after re-encoding it again.

Various scenarios for the cooperation among the relays can be implemented. A general cooperation scenario, denoted as C(m) ($1 \le m \le N - 1$), can be implemented in which each relay combines the signals received from the m previous relays along with that received from the source. The multi relay decode and forward scenario is show in Fig-15, in which each relay combines the signals received from all of the previous relays along with that from the source. In all of the considered cooperation scenarios, the destination coherently combines the signals received from the source and all of the relays. In the sequel, we focus on presenting the system model for a general cooperative scheme C(m) for any $1 \le m \le N - 1$. For a general scheme C(m), $1 \le m \le N - 1$, each relay decodes the information after combining the signals received from the source and the previous m relays. We consider 2relays for simulation purpose.

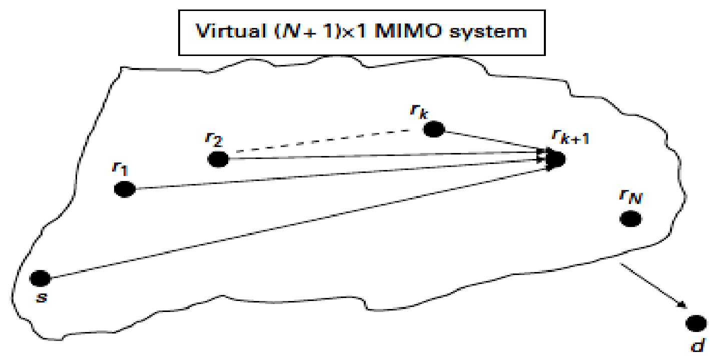

Fig 15: Illustration of Multi relay cooperation [18]

In General Multi Node cooperation protocol has (N +1) phases as stated in AF section but three in our case. In phase 1, the source transmits the information, and the received signal at the destination and the i-th (1st) relay can be modeled, respectively, as

$$Y_{sd} = \sqrt{Po}\, h_{sd}\, x + n_{sd} \qquad (32)$$

$$Y_{s,ri} = \sqrt{Po}\, h_{sri}\, x + n_{sri} \quad 1 \le i \le N \qquad (33)$$

Where P_o is the power transmitted at the source, x is the transmitted symbol, h_{sd} and h_{sri} are the channel fading coefficients between the source and the destination, and i^{th} relay, respectively. The terms n_{sd} and n_{sri} denote the AWGN. In phase 2, the 1st relay decodes the signal it receives from source, re-encode & send it to other (2nd in our case) relay & the destination.

Second relay combines the received signals from the source and the 1st relay using a maximal-ratio-combiner (MRC) as follow

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$$Y_{r2}=\sqrt{Po}h^{*}_{s,r2}\,Ys,r2\;+\sqrt{Pi}h^{*}_{r1,r2}\,Yr1,r2 \qquad (34)$$

Where $h_{r1,r2}$ is the channel fading coefficient between the 1st and the 2nd relay, $Y_{r1,\,r2}$ denotes the signal received at the 2nd relay from the 1st relay, and can be modeled as

$$Y_{r1,\,r2}=\sqrt{Pi}h_{r1,r2}x+n_{r1,r2} \qquad (35)$$

Where Pi is the power transmitted at relay 1, finally in phase (N + 1),

The destination coherently combines all of the received signals using an MRC as
Fo

$$Y_d=\sqrt{Po}h^{*}_{s,d}\,Ysd\;+\sum_{i=1}^{N}\sqrt{Pi}h^{*}_{ri,d}\,Yri,d \qquad (36)$$

4.4 Other Cooperation Strategies

Besides the two most common techniques for fixed relaying, there are other techniques, such as compress-and-forward cooperation and coded cooperation.

a. Compress and Forward

The main difference between compress-and-forward and decode/amplify-and-forward is that while in the later the relay transmits a copy of the received message, in compress and forward the relay transmits a quantized and compressed version of the received message. Therefore, the destination node will perform the reception functions by combining the received message from the source node and its quantized and compressed version from the relay node.

The quantization and compression process at the relay node is a process of source encoding, i.e.., the representation of each possible received message as a sequence of symbols. For clarity and simplicity, let us assume that these symbols are binary digits (bits). At the destination node, an estimate of the quantized and compressed message is obtained by decoding the received sequence of bits. This decoding operation simply involves the mapping of the received bits into a set of values that estimate the transmitted message. This mapping process normally involves the introduction of distortion (associated to the quantization and compression process), which can be considered as a form of noise. [12] & [13]

b. Coded Cooperation

Coded cooperation differs from the previous schemes in that the cooperation is implemented at the level of the channel coding subsystem. Note that both the amplify-and-forward and the decode-and-forward schemes are based on schemes where the relay repeats the bits sent by the source. In coded cooperation the relay sends incremental redundancy, which when combined at the receiver with the codeword sent by the source, results in a codeword with larger redundancy. [14]

4.5 Adaptive Cooperation Strategies

Fixed relaying has the advantage of easy implementation, but the disadvantage of low bandwidth efficiency. This is because half of the channel resources are allocated to the relay for transmission, which reduces the overall rate. This is true especially when the source–destination channel is not very bad, because in such a scenario a high percentage of the packets transmitted by the source to the destination could be received correctly by the destination and the relay's transmissions would be wasted. To overcome this problem, adaptive relaying protocols can be developed to improve the inefficiency. We consider two strategies: selective DF relaying and incremental relaying.[18]

a. Selective DF Relaying

In a selective DF relaying scheme, if the signal-to-noise ratio of a signal received at the relay exceeds a certain threshold, the relay decodes the received signal and forwards the decoded information to the destination. On the other hand, if the channel between the source and the relay suffers a severe fading such that the signal-to-noise ratio falls below the threshold, the relay idles. Selective relaying improves upon the performance of fixed DF relaying, as the threshold at the relay can be determined to overcome the inherent problem in fixed DF relaying in which the relay forwards all decoded signals to the destination although some decoded signals are incorrect. For simplicity, selective DF relaying is sometime simply called DF relaying without the confusion from fixed DF relaying. If the SNR in the source–relay link exceeds the threshold, the relay is likely able to decode the source's signal correctly. In this case, the SNR of the combined MRC signal at the destination is the sum of the received SNR from the source and the relay.

b. Incremental Relaying

For incremental relaying, it is assumed that there is a feedback channel from the destination to the relay. The destination sends an acknowledgement to the relay if it was able to receive the source's message correctly in the first transmission phase, so the relay does not need to transmit. This protocol has the best spectral efficiency among the previously described protocols because the relay does not always need to transmit, and hence the second transmission phase becomes opportunistic depending on the channel state condition of the direct channel between the source and the destination. Nevertheless, incremental relaying achieves a diversity order of two as describe below.

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In incremental relaying, if the source transmission in the first phase was successful, then there is no second phase and the source transmits new information in the next time slot. On the other hand, if the source transmission was not successful in the first phase, the relay can use any of the fixed relaying protocols to transmit the source signal from the first phase. Note that the transmission rate is random in incremental relaying. If the first phase was successful, the transmission rate is R, while if the first transmission was in outage the transmission rate becomes R/2 as in fixed relaying.

5. COOPERATIVE RELAYING ARCHITECTURES

5.1 General Design Issues

Cooperative communication systems could be realized in many ways. In this section we describe some choices and general design parameters that impact the realization of cooperative relaying protocols [10].

a. Transparent Versus Regenerative Relaying

One of the foremost design drivers in cooperative systems is the choice between transparent and regenerative relaying approaches. Transparent relaying generally implies that the relay performs some linear or non-linear operation in the analog domain, such as amplification, phase shifting, etc. Regenerative relaying, on the other hand, requires the relay to change the waveform and/or the information contents by performing some processing in the digital domain. An example is the relay receiving the information from the source, decoding, re-encoding and finally retransmitting it.

b. Traditional Versus Distributed Relaying

Another important factor is the choice between traditional relaying and spatially distributed space–time processing relaying architectures as shown in Fig-16. Traditional relaying is realized by means of an arbitrary number of serial and/or parallel relays delivering the information from source towards destination. Space–time relaying, however, is realized by means of a distributed deployment of a number of synchronized nodes performing one of the forms of distributed space–time processing, such as space–time coding, BLAST type algorithms or beam forming.

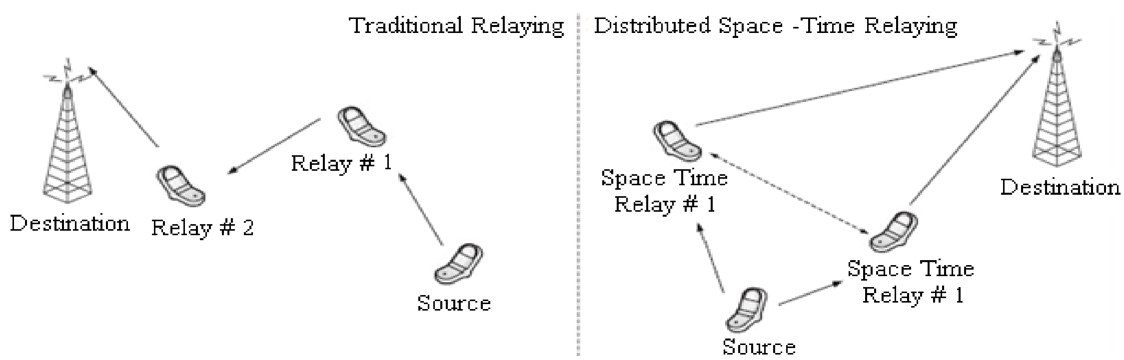

Fig 16: Choice between traditional and distributed relaying [10]

c. Dual-Hop Versus Multi-Hop Relaying

The choice of the number of relaying stages is very important to system designers. As such, relays can be connected in series or operated in parallel. Increasing the number of serial relaying nodes increases the path loss gain. Increasing the number of parallel relaying nodes increases the maximum diversity gain.

d. Availability Of Direct Link

Depending on the propagation conditions, there may or may not be a direct link available between source and destination. The direct link is usually available in situations where the system is capacity limited and not available where coverage limited. This is illustrated in the Fig-17 below.

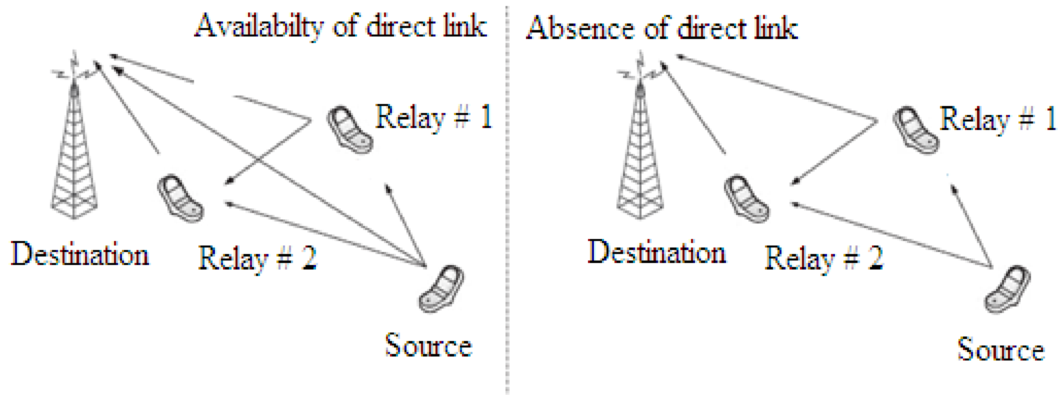

Fig 17: Illustration of presence and absence of a direct link [10]

e. Degree Of Cooperation

This refers to either supportive or cooperative relaying. Typically, placing a relay node in between a source and destination node is referred to as supportive relaying or simply relaying. Supportive relaying can be extended to cooperative communications, where at least two cooperative nodes are each other's respective relays at the same time to boost the other's communication links. This is illustrated in Fig-18.

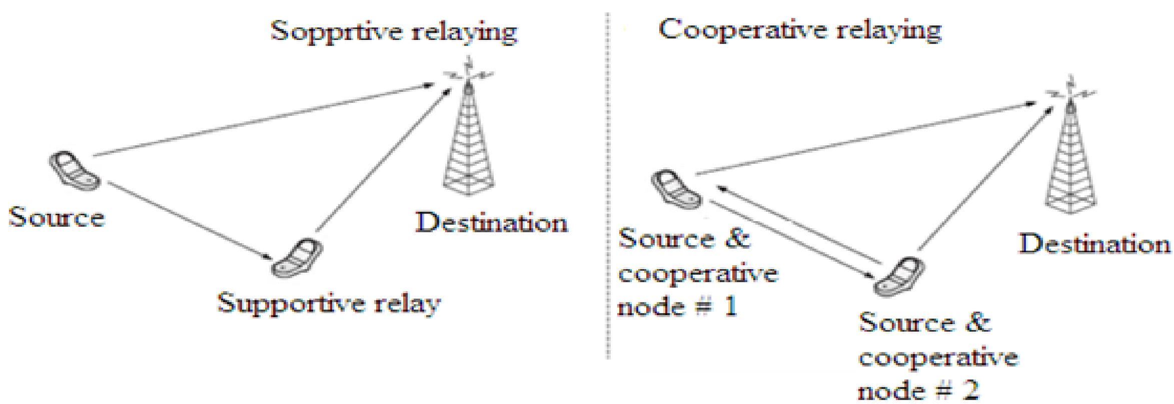

Fig 18: Choice between supportive and cooperative relaying [10]

f. Reception Models

There are two different reception models, non-orthogonal and orthogonal. In the former SNR varies with the square of distance and in the latter SNR is constant. Orthogonal scheme is faster. An orthogonal scheme usually makes use of MRC whereas non-orthogonal uses simple addition as described in Fig-19 [8].

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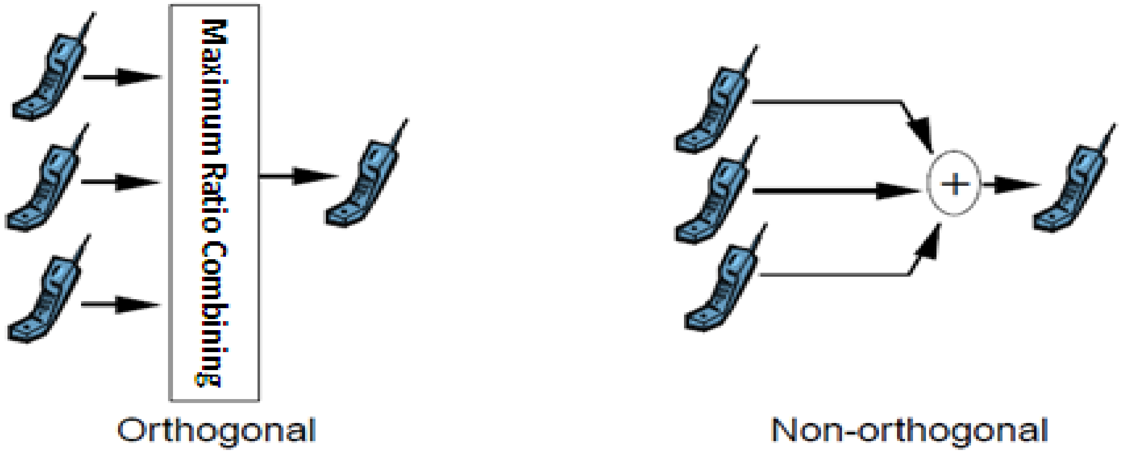

Fig 19: Orthogonal vs. non-orthogonal reception [8]

5.2 Protocol Architecture

It is the architecture that facilitates as well as limits the implementation of a cooperative relaying protocol. Architecture for AF protocol is purely analog but it can also be realized using a digital hardware. On the other hand DF protocol can only be implemented using digital architecture. The choice of protocol architecture also affects the choice of duplexing method and multiple access schemes to be used. These issues are discussed in detail in following sections [10].

a. Af Protocol Architecture

The hardware architecture required for realizing the AF protocol is illustrated in
Fig-20. The most important components of AF protocol architecture are described below:

- **Antenna**

The antenna converts the EM wave into current and vice versa for Rx and Tx respectively.

- **Receive Band Pass Filter**

The filter will receive the desired frequency components and remove the noisy components from the received signal.

- **Low Noise Amplifier**

The role of the LNA is to amplify the received signal from the power levels (around nA to µA) to power levels at which the RF section can operate without being disturbed by thermal noise (around mA).

- **Synthesizer**

The role of the synthesizer is to produce a reference frequency that translates the received signal onto a different frequency band. The synthesizer is usually composed of a phased locked loop (PLL) and a simple or voltage controlled oscillator (VCO).

- **Band Pass Filter**

The frequency shift by means of the synthesizer usually not only translates the signal of interest but also creates mirror spectral components of the desired signal at lower and higher frequencies. These clearly need to be eliminated, which is why a simple band pass filter is used after the synthesizer.

- **Power Amplifier**

The role of the power amplifier is to amplify the signal power from circuit levels to transmit power levels. Short range systems typically use around 0 dBm output power and long range systems from 20–40 dBm.

- **Transmit Band Pass Filter**

Since the PA does not have fully linear amplification characteristics it usually produces spurious emissions that need to be filtered by a suitable transmit BPF centered to the new transmit frequency.

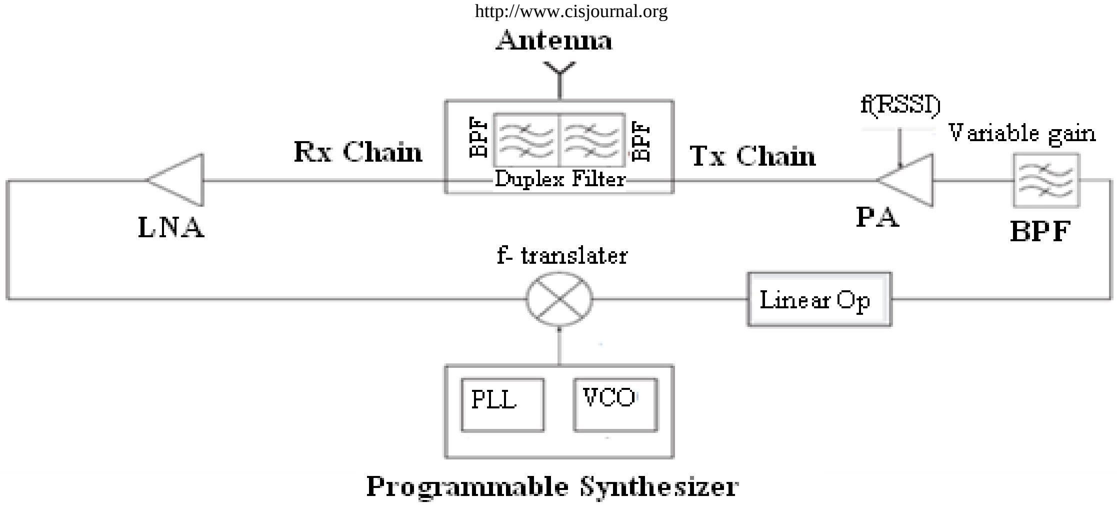

Fig 20: AF protocol hardware architecture realizing [10]

A.1 Key Characteristics

In the amplify-and-forward approach the relay down-converts the received analog signal, amplifies it and up-converts it to another frequency band prior to re-transmitting it as shown in the above figure. AF protocol is characterized by a variable frequency shift that allows the system dynamically to configure the duplexing bands so that interference is minimized. This protocol suffers from severe performance losses at low SNRs, because noise at the relay is also amplified. Furthermore, the analog signal cannot be stored, so it cannot be used in TDR mode. Also this requires immediate frequency translation. This implies two oscillators, two frequency bands and two good filters. AF protocol can only support simple multiple access protocols, TDMA or FDMA [1] & [7].

b. DF Protocol Architecture

The hardware architecture for DF protocol realization is depicted in Fig-21. The components of that architecture are discussed below [10]:

- **Intermediate Frequency Stage (IF)**

The received signal is first down converted to an intermediate frequency. Typical IFs are in the range of a several hundred MHz.

- **I And Q Branches**

It consists of a splitter which divides the IF into I and Q components which are then multiplied with the cosine wave and sine wave oscillators respectively. The resultant signal streams are orthogonal to each other and can hence be processed separately.

- **Adc And Dac Converter**

ADC is needed to convert the received signal to its digital form so that some signal processing could be performed. Prior to transmission, the digital signal is transformed back into analog signal by means of a DAC.

- **Digital signal processing**

The signal operations are carried out in the digital domain, which requires elements such as matched filters, microprocessors, memory, clock, etc. An important design point is which digital architecture to use that is FPGA, DSP, ASIC, etc. Typical transceiver architectures choose to use an FPGA for fairly heavy processing done at sampling level, such as matched filtering, multipath delay estimation, descrambler and de-spreader, integrator, and sometimes even channel estimation etc and one or several DSPs for operations at symbol level, such as detection, rake combining, Fourier transforms, etc.

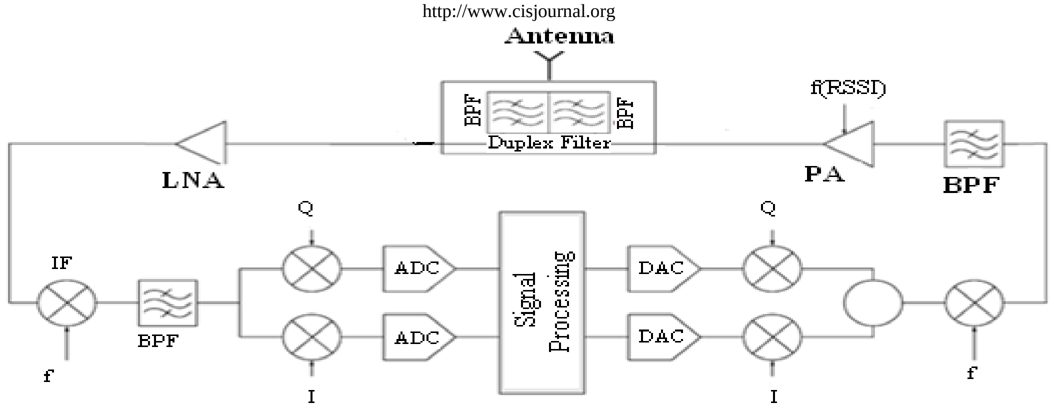

Fig 21: DF protocol hardware architecture realizing [10]

B.1 Key Characteristics

The decode-and-forward approach decodes the received signal and re-encodes it with a different code prior to re-transmission. This adds some complexity but at low SNR it exhibits a better performance than the AF approach. Unlike AF protocol, DF makes use of a single band but uses different time slots. Furthermore, to facilitate a coherent reception of I and Q branches, the receiver needs to be synchronized to the incoming data stream. Since the signal can be stored, this permits the use of both TDR and FDR modes. In addition to FDMA and TDMA access methods it also supports CDMA and OFDMA [1] & [7].

6. SIMULATION RESULTS

6.1 Introduction

In this section we show and discuss the Simulation result of two Cooperative Communication protocols i.e. AF & DF. We consider both single relay as well as Multi relay case for both stated protocols. All the simulation has been carried out using Matlab.

6.2 Simulation Block Diagram

Before we start our discussion on simulation results it is necessary to show a simulation diagram for better understanding. Beneath a diagram (fig-22) is shown that explain the follow of our simulation.

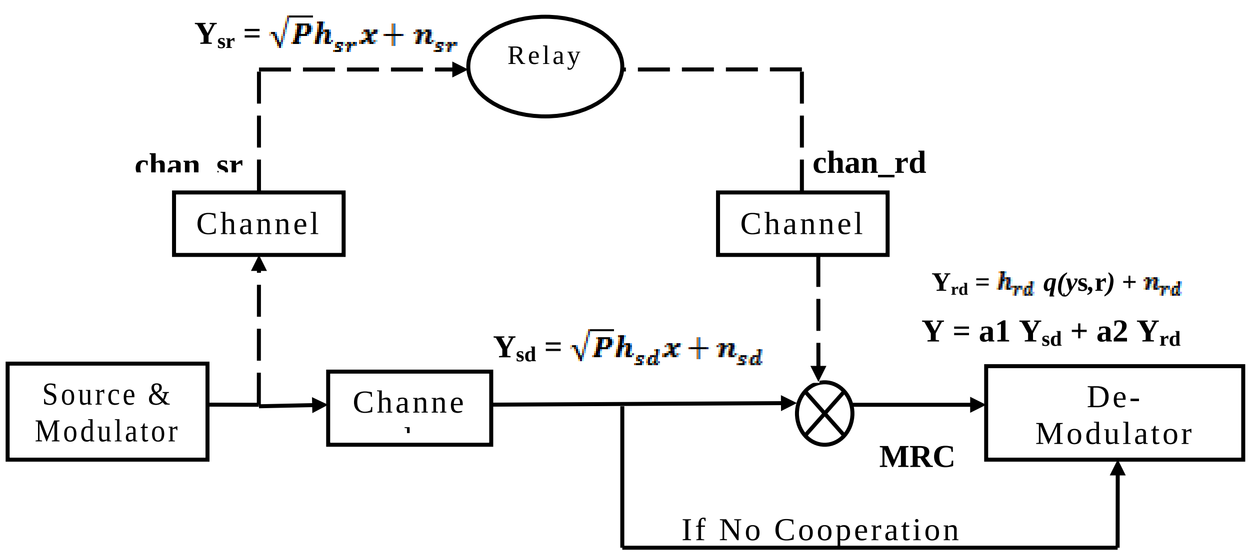

Fig 22: Simulation Block Diagram

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This block diagram shows graphical representation of our simulation code along with corresponding Variables used in our codes. First a Data is generated by the source which is modulated by a modulator, latter it is sent to both destination as well as relay (In case of Co-Op Communication). Relay process, the signal it received, according to implemented protocol & then transmit it to the destination. Finally relayed & direct path signals are combined at destination, demodulated & delivered to Destination.

6.3 Simulation Results

In this section, we will show & discuss simulation results of both single & multi relay cooperative communications. We focus on the Bit error rate (BER) performance analysis of both an amplify-and-forward (AF) & Decode-and-forward (DF) cooperation protocol.

a. Amplify and Forward (Single Relay)

Table 1: Simulation Parameter of AF-Single Relay

Protocol Used/Relay Mode	Fixed Amplify & Forward
No: of Bits	100e3
Modulation Scheme	BPSK
No: Relays	1
SNR Vector	0 to 10 dB
Combining Technique	Maximal ratio combiner

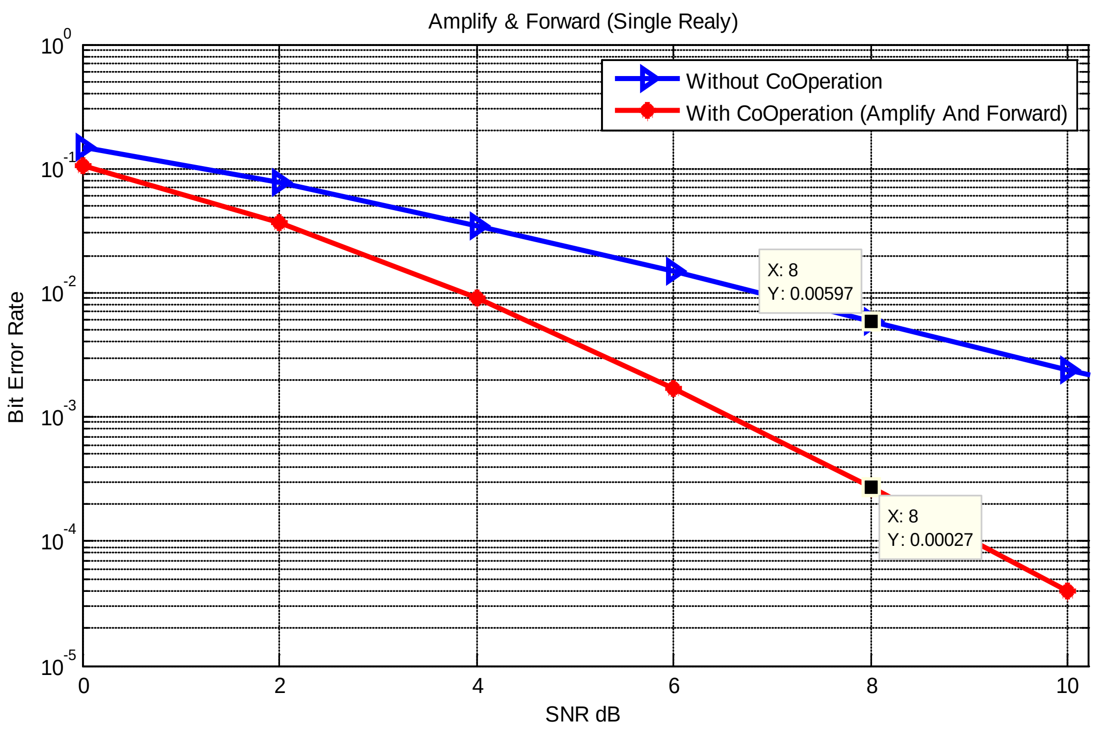

Fig 23: Simulation Result of AF-Single Relay

A.1 Discussion

The graph shows curves of Direct Signal (when No Co-Op Comm. is used) & Relayed signal. These curves are plotted against BER & SNR when single relay is used and operated in AF mode. A graph shows that there is a 0.57% BER improvement is achieved with the help of Relay operating in AF mode.

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b. Amplify and Forward (Multi relay)

Multi-node AF protocol has two relaying strategies as discussed in section-4.

B.1 Source-Only Amplify and Forward Relaying

Table 2: Simulation Parameter of AF-Multi Relay (Source Only Cooperation)

Protocol Used/Relay Mode	**Fixed Amplify & Forward (Source Only Cooperation)**
No: of Bits	100e3
Modulation Scheme	BPSK
No: Relays	2
SNR Vector	0 to 10 dB
Combining Technique	Maximal ratio combiner

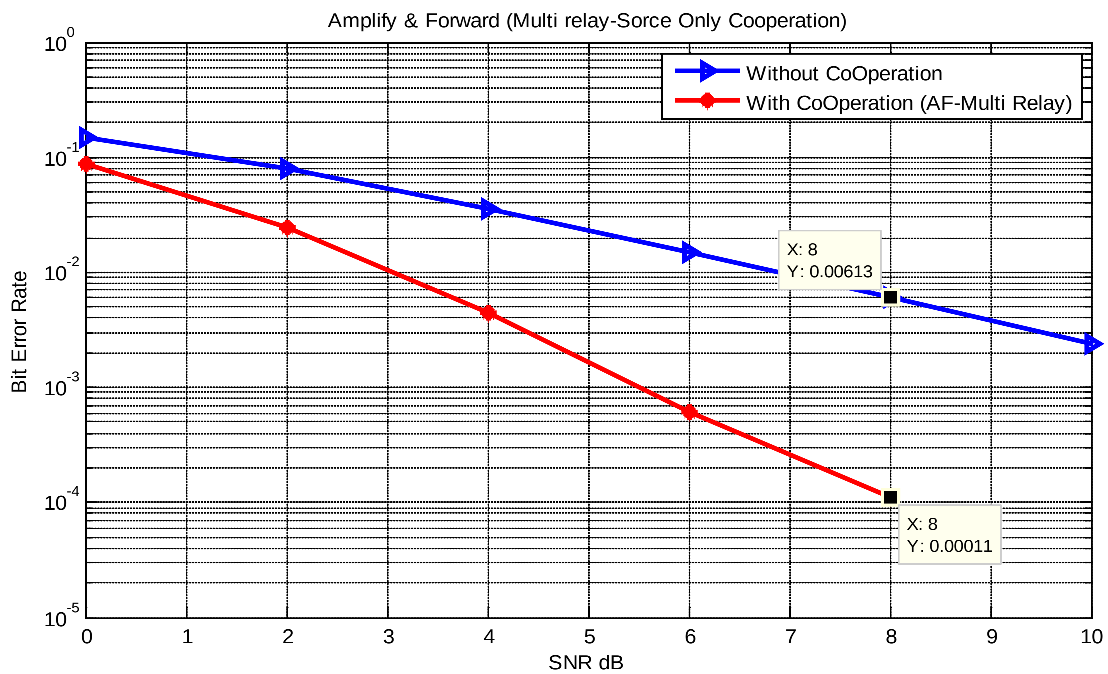

Fig 24: Simulation Result of AF-Multi Relay (Source Only Cooperation) [At the end]

B.1.1 Discussion

The graph shows the improvement with Multi-Relay Scheme. These curves are plotted against BER & SNR when two relay are used and operated in AF mode with selfish nature (Source Only Amplify- Forward). This graph clearly demonstrates that a more gain is achieved with the cooperation of two Relays as compared to single Relay. I.e. there is a 0.60% BER improvement is achieved with the help of two Relay operating in AF mode.

B.2 Multi Relay Cooperation Based Amplify & Forward Relaying.

Table 6.3 Simulation parameter of AF-Multi Relay (Multi relay Cooperation)

Protocol Used/Relay Mode	**Fixed Amplify & Forward (Multi Relay Cooperation)**
No: of Bits	1000e3
Modulation Scheme	BPSK

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No: Relays	2
SNR	0 to 10 dB
Combining Technique	Maximal ratio combiner

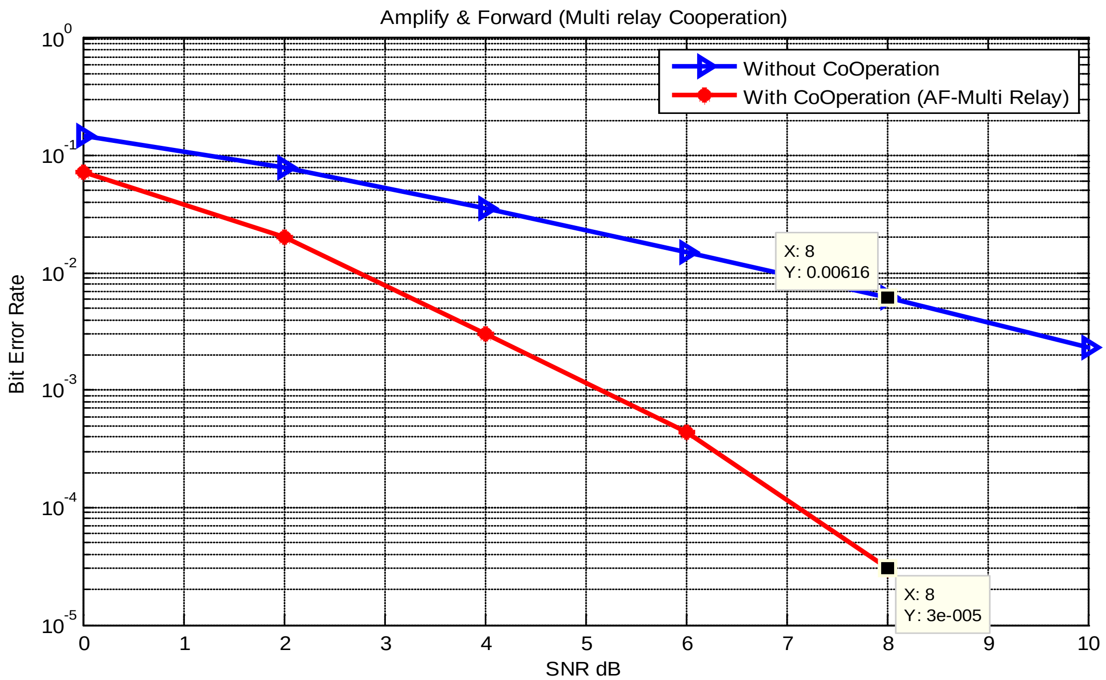

Fig 25: Simulation Result of AF-Multi Relay (Multi relay Cooperation) [At the End]

B.2.1 Discussion

Above graph shows the effect of Multi relay cooperation i.e. each node Cooperates with succeeding node also. With Multi relay cooperation we have much better performance than that of single node cooperation & Source Only AF relaying scheme. In this case there is a 0.62% BER improvement is achieved with the help of two Relay operating in AF mode.

c. Decode and Forward (Single Relay)

Table 6.4 Simulation Parameter of DF-Single Relay

Protocol Used/Relay Mode	Fixed Decode & Forward
No: of Bits	100e3
Modulation Scheme	BPSK
No: Relays	1
SNR	0 to 10 dB
Combining Technique	Maximal ratio combiner

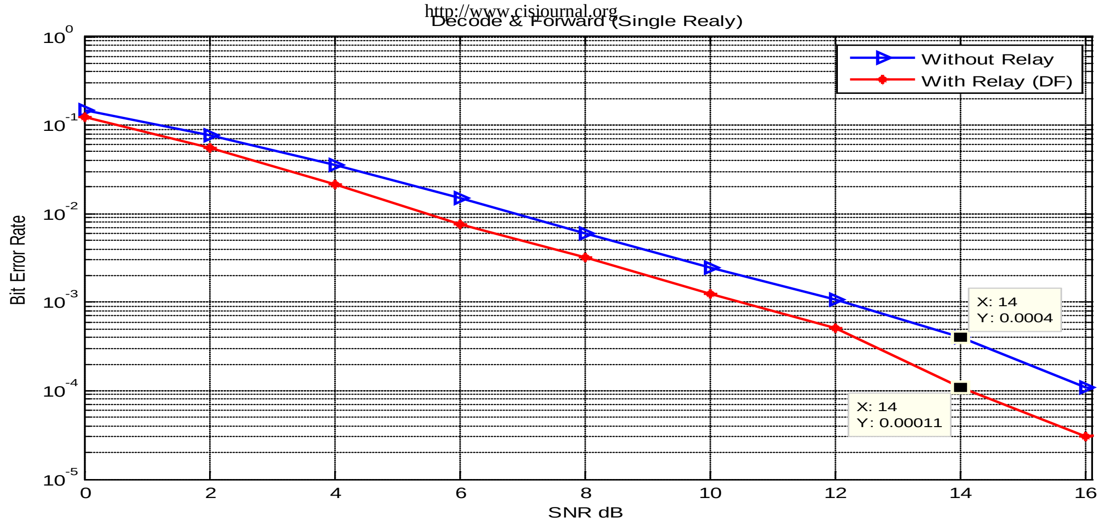

Fig 26: Simulation Result of DF-Single Relay [At the End]

C.1 Discussion

Above graph shows Direct & Relayed signal when relay operates in DF mode. In this case one relay is use With DF Scheme although significant gain is not achieved as compare to AF but fixed DF relaying has the advantage over AF relaying in reducing the effects of additive noise at the relay, it entails the possibility of forwarding erroneously detected signals to the destination if decoded wrongly, causing error propagation that can diminish the performance of the system.

d. Multi relay Decode and Forward

Table 6.5 Simulation Parameter of DF-Multi Relay

Protocol Used/Relay Mode	Decode & Forward (Multi relay)
No: of Bits	100e3
Modulation Scheme	BPSK
No: Relays	2
SNR	0 to 10 dB
Combining Technique	Maximal ratio combiner

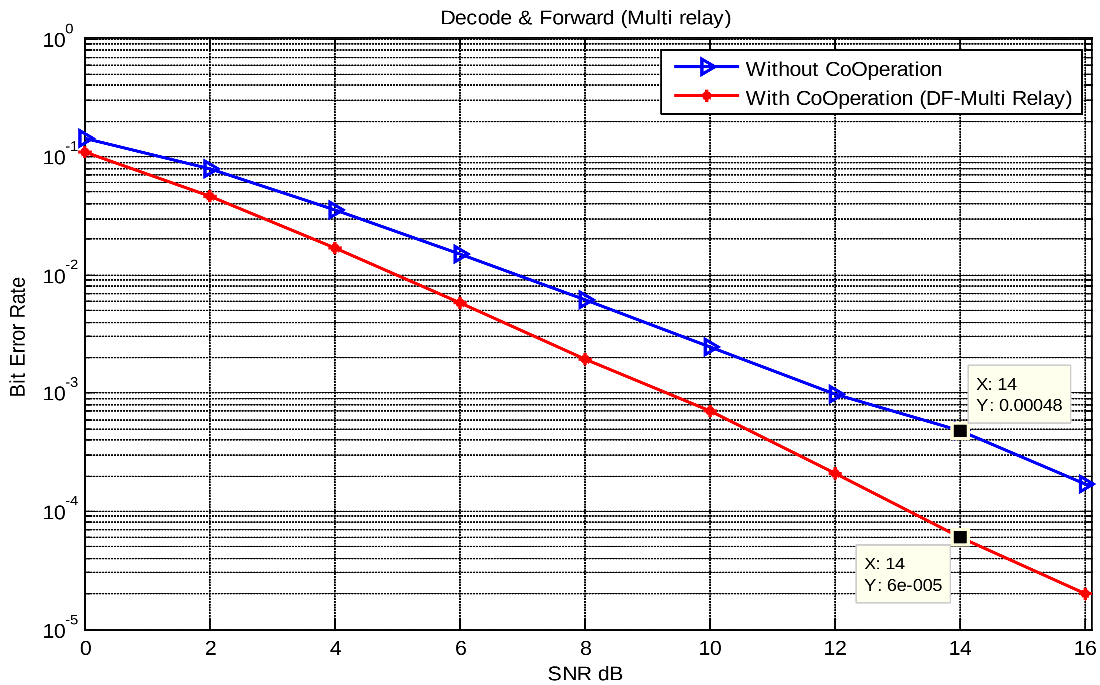

Fig 27: Simulation Result of DF-Multi Relay [At the End]

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D.1 Discussion

Above graph shows Direct & Relayed signal when relay operates in DF mode. These curves are plotted against BER & SNR when two relay are used and operated in DF scheme. Though Multi relay somehow improves the results but still significant gain is not achieved as compare to AF because DF protocol has a responsibility of reducing error propagation.

6.4 OFDM is a combination of modulation and multiplexing. Multiplexing generally refers to independent signals, those produced by different sources. So it is a question of how to share the spectrum with these users. In OFDM the question of multiplexing is applied to independent signals but these independent signals are a sub-set of the one main signal. In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier.

OFDM is a special case of Frequency Division Multiplex (FDM). As an analogy, a FDM channel is like water flow out of a faucet, in contrast the OFDM signal is like a shower. In a faucet all water comes in one big stream and cannot be sub-divided. OFDM shower is made up of a lot of little streams.[25]

7. CHALLENGES, SYSTEM TRADEOFFS AND CONCLUSION

7.1 Challenges

Helping out other users in a cooperative fashion has its price. In this section, we will describe the challenges that incur in systems with cooperative communication incorporated [7] & [10].

- **Complex Schedulers**

Relaying requires more sophisticated schedulers since not only traffic of different users and applications needs to be scheduled but also the relayed data flows. This function decides how many resources are scheduled for a single user (or relay node). This function affects the achieved throughput of the system. Practical implementations of a scheduler also consider Automatic Repeat-Request (ARQ) protocols and Quality-of-Service (QOS) classes, which experience different priorities in the scheduling process.

- **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.

- **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. So cooperative relying is more suitable for 3G/4G systems which are more tolerant to interference. Many Interference mitigation schemes has been proposed for cooperative communication. Like a successive interference cancellation (SIC) scheme for cooperative communication systems in wireless communication network. In the interference cancellation strategy, co-channel interference (CCI) is mitigated by zero forcing (ZF) or minimum mean square error (MMSE) receivers. Moreover, successive interference cancellation (SIC) with optimal ordering algorithm is applied for rejecting CCI efficiently. Orthogonal complementary (OC) codes are inherently immune to MAI is proposed for Cooperative Communication. To efficiently utilize the scarce radio spectrum and codes, a centralized medium access control (MAC) protocol is also proposed to coordinate the code assignment and channel access among users and relays.[19] & [20]

- **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 interleavers, such as utilized in GSM voice traffic. To circumvent this latency, either simple transparent relaying (i.e. AF relaying) or some advanced decoding methods need to be used.

- More Channel Estimates

The use of relays effectively increases the number of wireless channels. This requires the estimation of more channel coefficients and hence more pilot symbols need to be provided if coherent modulation was to be used.

7.2 System Tradeoffs

These factors essentially lead to tradeoffs. Hence, many system design parameters can be traded against one another [10].

- **Coverage versus Capacity**

Cooperative systems allow coverage to be traded against capacity or equivalently diversity versus multiplexing gains. Therefore, the system designer has the choice to let a relay help boost capacity or increase the coverage. Increasing one inherently diminishes the other.

- **Algorithmic versus Hardware Complexity**

Solving the coverage and capacity problem by means of more cellular base stations requires more complex and hence costly hardware. Relays, on the other hand, are of relatively low hardware complexity. However, the decrease in hardware complexity by using relays yields an increase in algorithmic complexity since scheduling, synchronization, handover and other algorithms become significantly more complex. An optimum solution trading algorithmic with hardware complexity hence needs to be determined.

- **Interference versus Performance**

Cooperative communications yields gains which can either be used to decrease the transmission power and hence generated interference or increase capacity/coverage. Furthermore, relaying generates extra traffic, which is an additional source of interference.

- **Ease-of-Deployment versus Performance**

Relays can be deployed in a planned and unplanned manner. In the former the network designer optimizes the placement and parameterization of the static relay node. This is a complex task but leads to superior performance. In the latter, relays are deployed in an unplanned manner and hence can be stationary or mobile, deployment is therefore significantly simplified at the cost of decreased performance w.r.t. the planned roll-out.

- **Cost versus Performance**

Being a traditional trade-off, the cost of the chosen cooperative solution has a profound impact on its performance. Deploying highly complex relaying nodes like cooperative space–time relaying induces high costs but also improved performance.

8. CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

In a cooperative cellular communication system two or more active users in a network share their antennas and jointly transmit their messages, either simultaneously or at different times to obtain greater reliability and efficiency than they could obtain individually. Through cooperation both terminals are able to simultaneously increase their throughputs and reliabilities even when they are connected via low quality links, or when one terminal has a much better link then the other. In our paper work we presented the scenario of cooperative communication in cellular systems. We discuss how this technique can be used to exploit MIMO benefits in a distributed way. Several relaying schemes for cooperative communication are presented. Practical implications and requirements on system design are also discussed.

Throughout this paper we focused on only two Protocols viz AF & DF but there are many other protocols as well that deserve attention. We also didn't include Power Allocation i.e at what power source/relay should transmit when in Co-Op System without causing interference for others. Another important aspect of Co-Op Communication which is missing in this paper is Relay Selection, it is important to understand "when to cooperate and with whom" so it should be explored in future. Now something from simulation point of view, since Co-Op is purposed for 4G systems so it is better to have OFDM modulation scheme rather BPSK or any other PSK scheme. One more thing, we consider only single tap which is very impractical so in future multi-tap should be introduced in order to measure the performance of Cooperative communication in the presence of multipath.

REFERENCES

[1] Murat Uysal, 'Cooperative Communications for Improved Wireless Network Transmission: Framework for Virtual Antenna Array Applications' Information Science Reference, (2010) ISBN 978-1-60566-666-2

[2] Y.W. Peter Hong, Wan-Jen Huang & C.C. Jay Kuo, 'Cooperative communications and Networking: Technologies and System Design' Springer, (2010) ISBN: 1441971939

[3] Yu-Kwong Ricky Kwok, Vincent K. N. Lau, 'Wireless Internet and Mobile Computing: Interoperability and Performance' John Wiley & Sons, (2007) ISBN-13: 978-0471679684

[4] M.Patzold, 'Mobile fading Channels: Modeling, Analysis and Simulation'. John Wiley & Sons, (2002) ISBN-10: 0471495492

[5] Online :http://gaussianwaves.blogspot.com/2010/10/ber-vs-ebn0-for-qpsk-modulation-over.html (Last accessed on 10-01-2011)

[6] Online :http://www.wirelesscommunication.nl/reference/contents.htm(Last accessed on 10-12-2010)

[7] A. Nosratinia, T. E. Hunter, A. Hedayat, 'Cooperative Communication in Wireless Networks'. Communications Magazine, IEEE, Vol. 42, No. 10. (2004), pp. 74-80.

[8] Birsen, Sirkeci, ‘Distributed Distributed Cooperative Communication in Large-Scale Wireless Networks’. Cornell University 2006.

[9] Quang Trung Duong, ‘On Cooperative Communications and Its Application to Mobile Multimedia’ Blekinge Institute of Technology, 2010 ISBN: 978-91-7295-167-9

[10] Mischa Dohler, Yonghui Li, ‘Cooperative Communications Hardware, Channel & Phy’ John wiley & Sons, 2010 ISBN 978-0-470-99768-0

[11] Kai-Kit Wong, Murch R.D, Letaief K.B, ‘Performance Enhancement of Multiuser MIMO Wireless Communication Systems’. IEEE Transactions on communications, VOL. 50, NO. 12 (2002), pp. 1960 - 1970.

[12] T. Cover and A. E. Gamal, ‘Capacity theorems for the relay channel’. IEEE Transactions on Information Theory, 25(5):572–584 (1979). pp. 572-584.

[13] G. Kramer, M. Gastpar, and P. Gupta.’Cooperative strategies and capacity theorems for relay networks’. IEEE Transactions on Information Theory, 51(9):3037–306, (2005). pp. 3037-3063.

[14] M. Janani, A. Hedayat, T. E. Hunter, and A. Nosratinia, ‘coded cooperation in wireless communications: space-time transmission and iterative decoding’. IEEE Transactions on Signal Processing, 52:362–370, February 2004. pp. 362-371

[15] J. N. Laneman, D. N. C. Tse, and G. W. Wornell, ‘Cooperative diversity in wireless networks: efficient protocols and outage behavior’. IEEE Transactions on Information Theory, 50(12):3062–3080, December 2004. pp. 3062-3080

[16] A. K. Sadek, W. Su, and K. J. R. Liu, ‘A class of cooperative communication protocols for multi-node wireless networks’. In Proceedings of the IEEE International Workshop on Signal Processing Advances in Wireless Communications SPAWC, June 2005 pp. 560–564.

[17] J. N. Laneman and G.W. Wornell, ‘Distributed space-time coded protocols for exploiting cooperative diversity in wireless networks’. IEEE Transactions Information Theory, 49(10):2415–2425, October 2003. pp. 2415-2425

[18] K. J. Rayliu, Ahmed K. Sadek, Weifengsu, Andres Kwasinski, ‘Cooperative Communications and Networking’. Cambridge University Press, 2009 ISBN-13 978-0-511-46548-2

[19] Eun Cheol Kim, Jae Sang Cha ’Successive interference cancellation for cooperative communication systems’. International Conference on Hybrid Information Technology, 2009 pp. 652-656

[20] Kuang-Hao Liu, Hsiang-Yi Shin, Hsiao-Hwa Chen, ‘Interference-resistant cooperative wireless networks based on complementary codes’. John Wiley & Sons, 2009.

[21] Konstantinos Alexopoulos, ‘Performance Analysis of Decode-and-Forward with Cooperative Diversity and Alamouti Cooperative Space-Time Coding in Clustered Multihop Wireless Networks’. N.P.S Monterey California 2008

[22] Randy H. Katz, ’CS 294-7: Radio Propagation’. University of California Berkeley, CA 94720-1776, 1996

[23] R. U. Nabar, H. Bolcskei and F.W. Kneubuhler, ‘Fading relay channels: performance limits and space-time signal design’. IEEE Journal on Communication, Aug 2004. pp. 1099 – 1109

[24] Meng Yu, Jing Li, ‘Is amplify-and-forward practically better than decode-and-forward or vice versa?’. IEEE International Conference on Acoustics, Speech and Signal Processing 2005Vol 3, pp iii/365 - iii/368

[25] Intuitive Guide to Principles of Communications. www.complextoreal.com