2.1 Introduction

The first inception of wireless communications was back in 1895 when "Guglielmo Marconi" transmitted a three-dot Morse code for the letter 'S' over a distance of three kilo meters using electromagnetic waves. Since then, wireless communication has gone through a remarkable evolution in terms of integrated circuitry and technological advances to the really complex networks. From satellite transmission, radio and television broadcast to the ongoing development of 4G for mobile communications all inspired by the never ending quest for higher throughput, higher reliability, higher data transfer and cost efficiency. Exploiting the technological development in radio hardware and integrated circuits, which allow for implementation of more complicated communication schemes, would require an evaluation of the fundamental performance limits of wireless networks [1].

A wireless network system can traditionally be viewed as a set of nodes trying to communicate with each other. However, from another point of view, because of the broadcast nature of wireless channels, one may think of those nodes as a set of antennas distributed in the wireless system. Transmission between these antennas suffers from much degradation which inspires considerable research on how to effectively combat these negative effects that impair signal transmission. Some of these channel problems will be outlined for a clearer understanding of the Cooperative Communication methodology [2].

Wireless communications is currently a highly demanded communication technology that is most functional in terms of mobile access. Since its inception, it has gone through lots of developmental phases to meet the ever increasing needs of its wide range of applications. The multipath fading, shadowing, and path loss effects of wireless channels are the biggest challenges in the history of wireless communications which has induced considerable research for possible solutions. These effects cause random variations of channel quality in time, frequency, and space that make conventional wire line communication techniques too difficult to employ in the wireless environment [3]. Despite numerous proposed solutions, methods of high efficacy were never realized until the proposition of diversity techniques in the past two decades. The use of diversity technology highly improves the performance of wireless communications as it gives the signals a separate fading path during transmission to exploit diversity in different channel dimensions, such as time, frequency, and space, and hence achieve diversity gains. In particular, advances in the theory of multiple input multiple output (MIMO) systems have made it desirable to equip modern wireless transceivers with multiple antennas in order to achieve spatial diversity gains. However, due to the limitation in terms of size and cost of wireless devices for many applications, e.g., in wireless sensor networks or in cellular phones, having multiple antennas on a single terminal is impractical [1] [2]. In such cases, creating a virtual MIMO environment where nodes can collaborate and share their antennas to form a distributed virtual MIMO antenna system is the easiest and most promising alternative to apply. This is achieved by the so called cooperative communications [4].

2.2 Related Work

In [5]: The author analyze the symbol-error-rate (SER) performance for a two-user amplify-and-forward cooperative system. By making use of M-PSK modulation, the closed-form SER formulation and corresponding upper bound are derived first. According to the SER performance analysis, the impact of relay location is discussed by making use of a simple line topology. If the power allocation to the source and relay is equal and draw an interesting conclusion that the SER performance in such topology shows a symmetry property and the optimum relay location is just in the middle with respect to the source and destination.

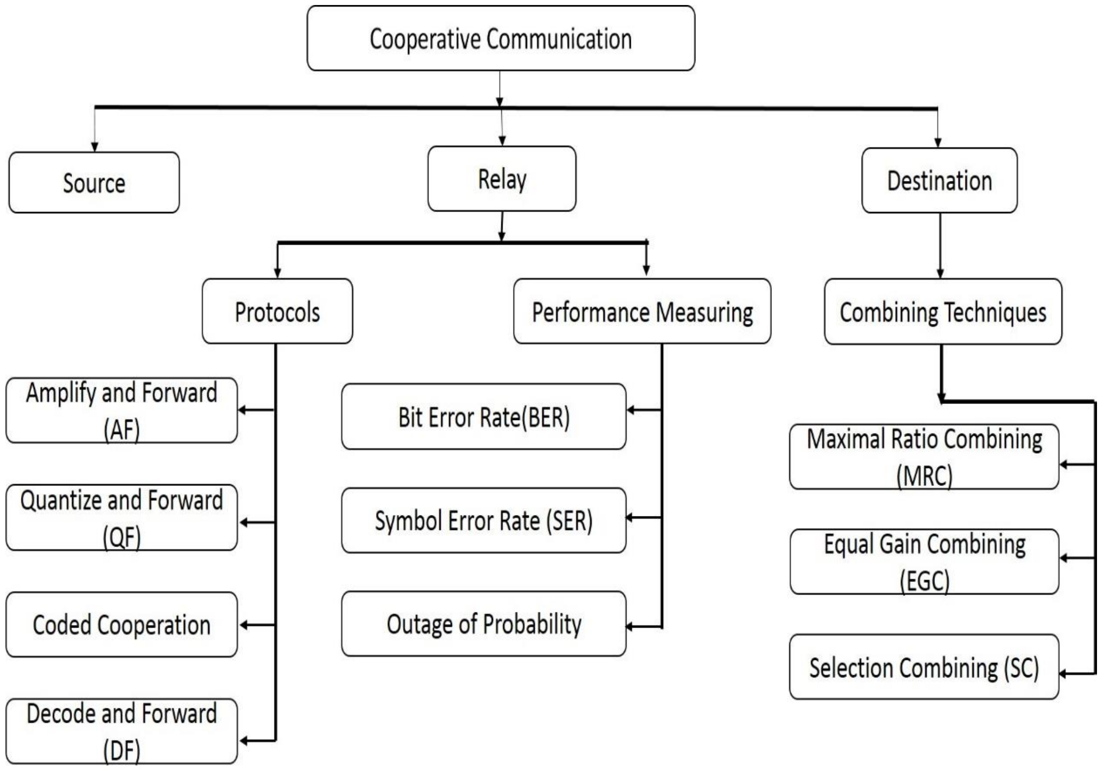
In [6]: The author examines a quantize-and-forward (QF) relaying approach that is amenable to implementation on resource-constrained relays. We describe QF relaying with M-ary phase shift keying (PSK) and derive the maximum likelihood-based soft-decision metric for this scheme. When each M-PSK channel symbol is quantized with q bits at the relay, simulation results show that quantizing with q = 1+log2M bits (i.e., only one extra bit per symbol) provides comparable performance in Rayleigh fading to the idealized (unquantized) AF protocol as well as to an adaptive decode and forward protocol at frame error rates of practical interest.

In [7]: The author generalization of the decode and forward (DF) and compress and forward (CF) relaying schemes is studied for the case in which Gaussian codebooks are used for signaling over scalar Gaussian memory less channels. Three SNR regions are identified where in the generalized DF-CF scheme reduces to either the DF or the CF scheme. In addition, it is shown that there is an SNR region in which the generalized DF-CF scheme can be more advantageous than both schemes.

In [8]: The author analyze the symbol error rate (SER) performance of decode and forward (DF) cooperative communications over Nakagami-m fading channels. The author then examine the SER in this scenario. In addition, by varying the parameters of the Nakagami-m fading channels in the analytical results, obtain some perceptions of choosing a good relay for enhancing the cooperation and make clear about how the included Nakagami fading figures and channel variances affect the SER performance. In addition, the optimal power allocation is investigated based on the derived asymptotic SER expressions. Simulations are finally provided to verify the correctness of our analysis.

2.3 Cooperative Communication Review

Cooperative communications refer to a type of communication system or technique that allows users to transmit each other's messages to the intended destination. Furthermore, the advent of the 4G mobile communication has introduced heterogeneous networks of various services that use different standards hence different terminals to deploy services [5]. The method involving the use of a single all-purpose device to deploy network services results in design complications resulting in inefficient use of battery power causing short battery life [2]. In such situations, cooperative communications enable users ease off the load on the network and thus increase the capacity as well as battery life for their devices [3].



2.4 The Relay Protocols

2.4.1 Amplify and Forward

The relay upon receives a noisy version of the signal transmitted by the source, then noisy signal is simply amplified and retransmitted to destination. Majority of the works done in the past in this area of cooperative diversity are based on the amplify-and-forward scheme [9].

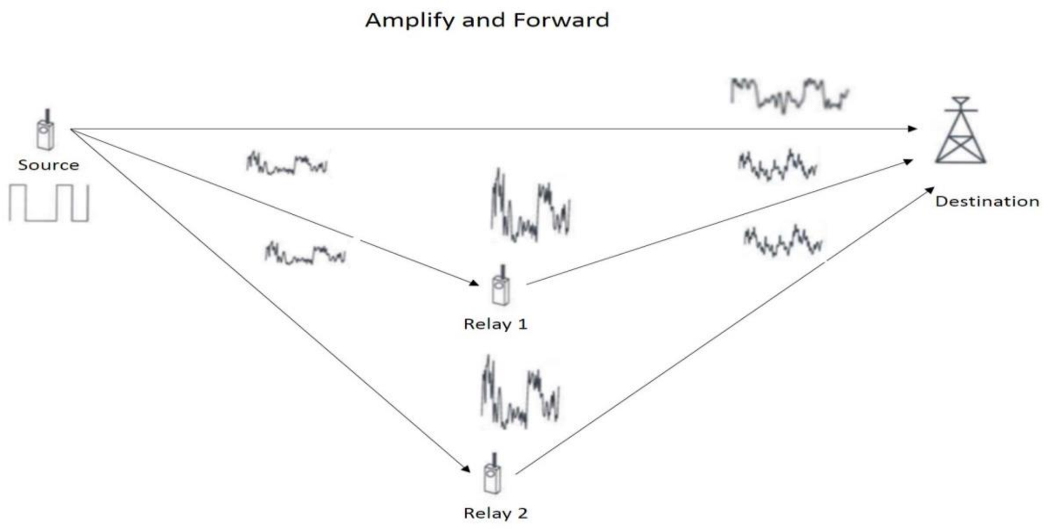


Figure 2.1: Amplify and Forward

2.4.2 Quantize and Forward

A straightforward implementation of QF relaying system that is similar to the AF relaying system. The initial purpose of quantization is to avoid the storage of analog samples, this approach however would require the relay to store the analog samples received from the source. Instead, a quantization scheme that does not necessitate the storage of analog values is proposed, where the relay separately quantizes the signal received in the source and then properly combines the quantized values [10].

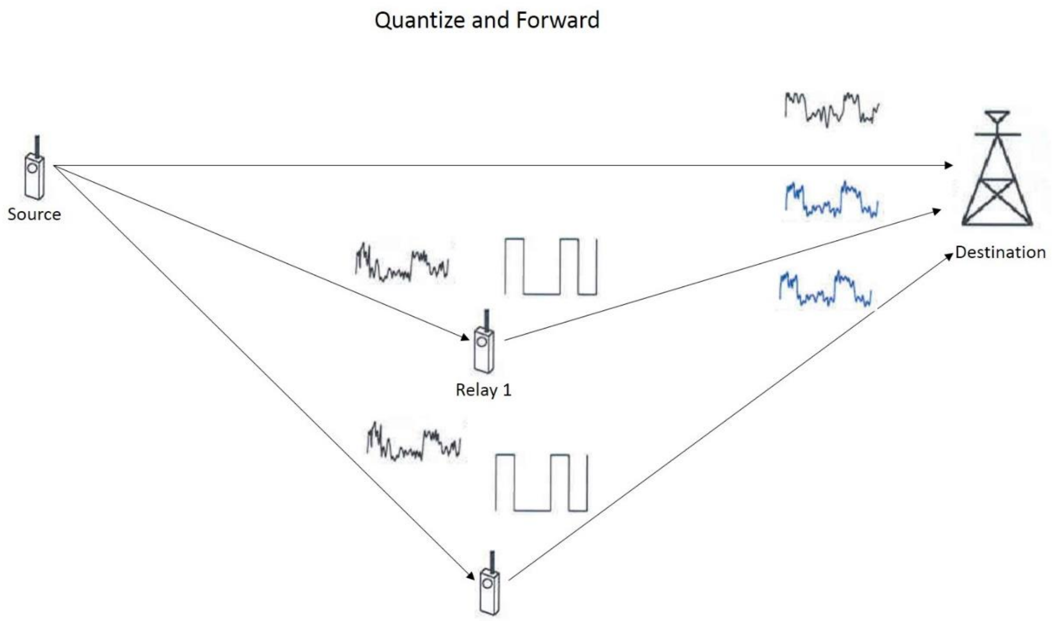


Figure 2.2: Quantize and Forward

2.4.3 Coded Cooperation Method

This method integrates cooperation into channel coding. It sends different portions of each user's code word via two independent fading paths. Each user tries to transmit incremental redundancy for its partner. Otherwise, the user revert to non-cooperative mode. No feedback between the users managed automatically through code design [11].

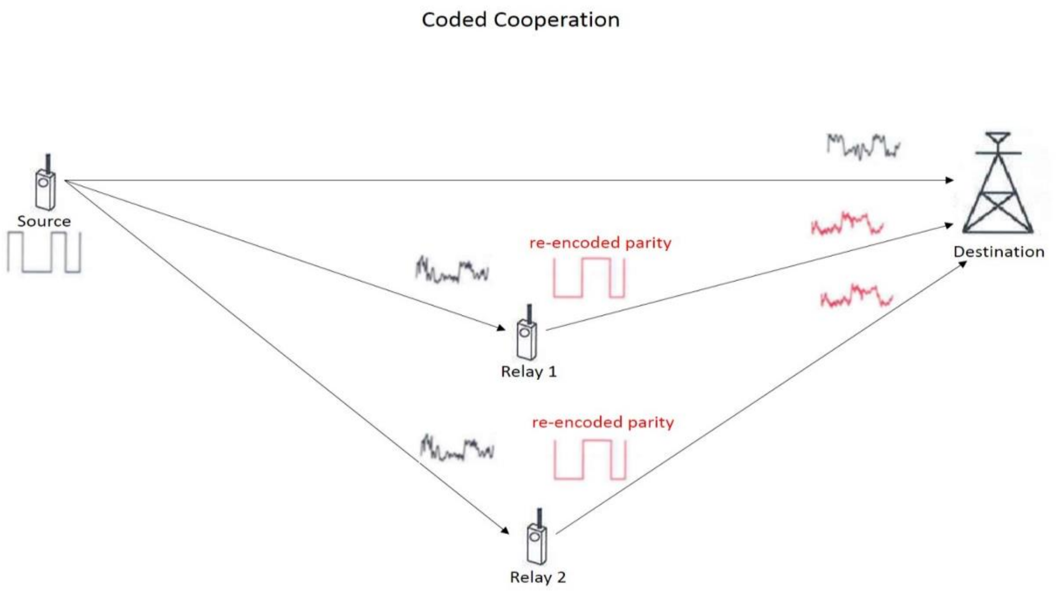


Figure 2.3: Coded Cooperation.

2.4.4 Decode and Forward

This strategy follows that the relay station decodes the received signal from the source node, re-encodes it and forwards it to the destination station. It is the most often preferred method to process data in the relay since there is no amplified noise in the signal sent. Signals can be decoded by the relay completely [6]. This takes a lot of computing time and CPU bandwidth. An error correcting code at the source makes it possible for received bit errors to be corrected at the relay station. In the absence of that, the relay can detect errors in the received signal using a checksum [2].

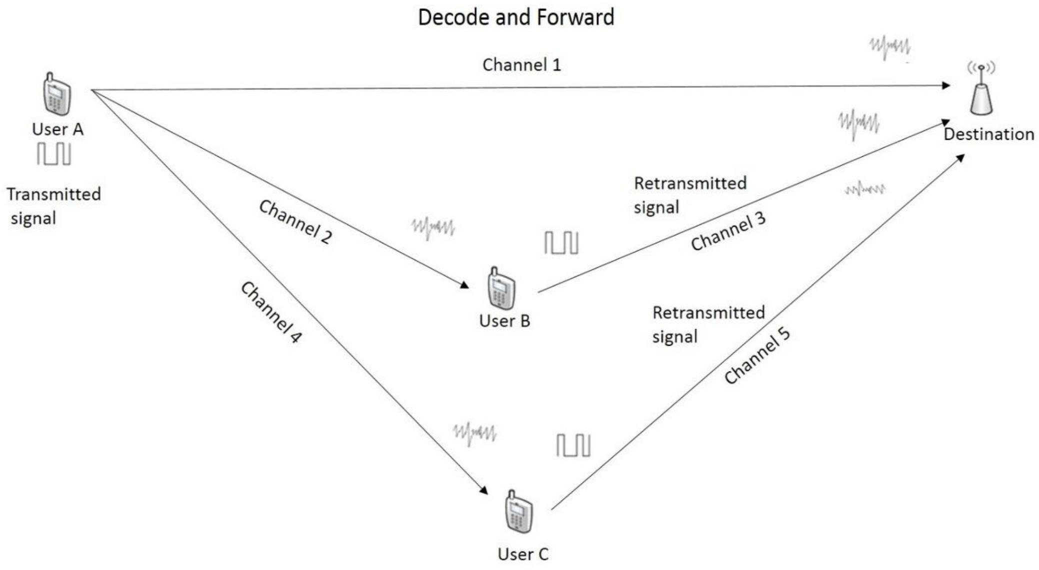


Figure 2.4: Decode and Forward

2.5 The performance of a wireless channel is measured at the physical level by

2.5.1 Bit Error Rate (BER)

Is defined as the percentage of bits that have errors due to noise, distortion or interference relative to the total number of bits received in a transmission [5].

2.5.2 Symbol Error Rate (SER)

Is defined as the percentage of 8bits that have errors due to noise, distortion or interference relative to the total number of bits received in a transmission [6].

2.5.3 Outage of Probability

Is defined as the probability that the instantaneous error probability exceeds a specified value or equivalently, the probability that the output SNR, falls below a certain specified threshold [5].

2.6 Receiver Combination Techniques

A diversity combining technique is used to combine the multiply received copies of a signal into a single improved signal before further signal processing takes place. Proper combining of the multiple signals will greatly reduce severity of fading and improve reliability of transmission [4].

2.6.1 Maximal Ratio Combining (MRC)

In maximal ratio combining (MRC) the output is a weighted sum of all branches, SNR of the combiner output is the sum of SNRs on each branch [3].

2.6.2 Equal-Gain Combining (EGC)

In this scheme, the receiver corrects the phase rotation of the received signals caused by the fading channel and combines the received signals of different paths with equal weight [6].

2.6.3 Selection Combining (SC)

In SC systems process only one of the diversity branches. Specifically, in its conventional form, the SC combiner chooses the branch with the highest SNR. In addition, since the output of the SC combiner is equal to the signal on only one of the branches [3].

2.7 Channel Impairments

Talking about channel impairments refer to conditions or factors that degrade or distort signals as they are transmitted through the channel from source to destination [8].

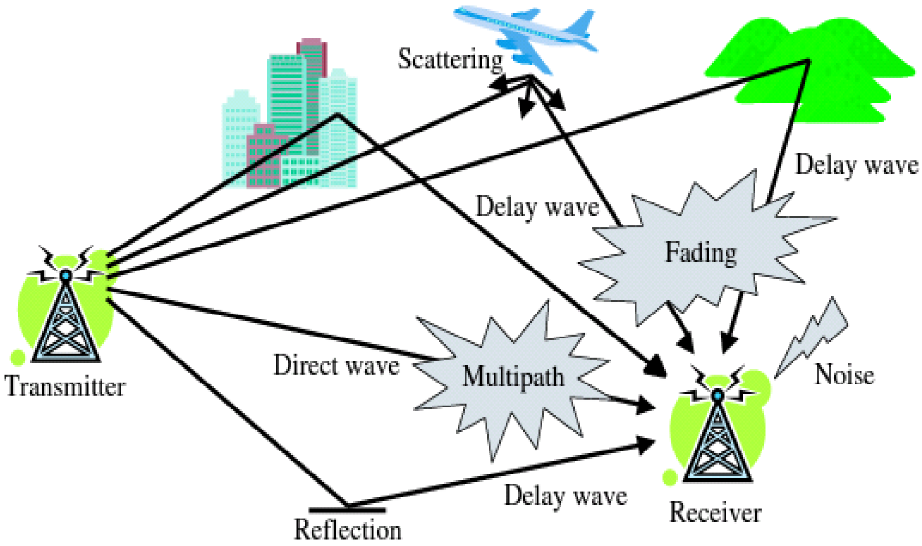


Figure 2.5: The Environment of Wireless Communications.

2.7.1 Path Loss

In a point-to-point wireless communication system, where a transmitter communicates with receiver by sending an electromagnetic signal through a wireless medium, the strength of the signal attenuates as it traverses the medium and thus, becomes weaker as the propagation distance increases. Beyond a certain distance, the attenuation becomes unacceptably great, and repeaters or amplifiers would be required to boost the signal at regular intervals [4] [7]. These problems are more complex when there are multiple receivers, where the distance from transmitter to receiver is variable [9].

2.7.2 Noise

Noise refers to any undesired signal in a communication system or unwanted disturbances superimposed on a useful signal, which tends to obscure its information content [4].

2.7.3 Fading

Fading refers to the distortion that a carrier modulated telecommunication signal experiences over certain propagation media. A fading channel is a communication channel that experiences fading. In wireless systems, fading is due to multipath propagation and is sometimes referred to as multipath induced fading [5]. In fading there are several models such as:

2.7.3.1 Rayleigh Fading Model

When radio communication link is non line of sight (NLOS), the small scale fading tends to be Rayleigh distributed. NLOS link has no direct path from the transmitter to the receiver.

The Rayleigh distribution will arises from the large number of indirect path when the link is NLOS [10].

2.7.3.2 Rician Fading Model

When there is line of sight, direct path is normally the strongest component goes into deeper fade compared to the multipath components [12].

2.7.4 Multipath Fading

In a wireless mobile system a signal can travel from transmitter to receiver through multiple reflective paths which is known as multipath propagation and is illustrated in Figure 2.6:

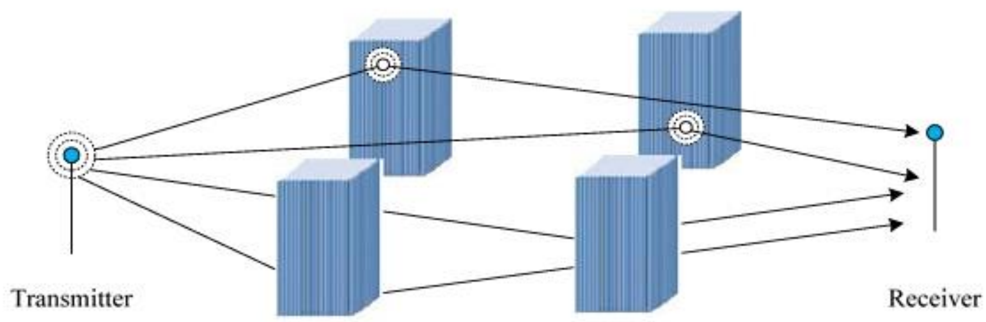


Figure 2.6: Multipath Propagation

There are basically many propagation mechanisms playing a role in the multipath fading:

- **Reflection**

This occurs when a propagating electromagnetic signal encounters a smooth surface that is large relative to the signal's wavelength [6]. An indication of this is shown in Figure 2.7.

- **Diffraction**

This occurs at the edge of a dense body that is larger compared to the signal's wavelength as indicated in Figure 2.7. It is termed shadowing because the signal can reach the receiver even if it encounters an impenetrable body [7].

- **Scattering**

This occurs when the propagating radio wave encounters a surface with dimensions on the order of the signal's wavelength or less and causes the incoming signal to spread out (scatter)into several weaker outgoings in all directions [6].

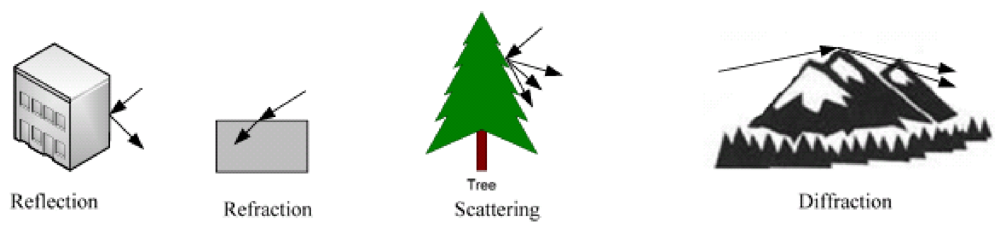


Figure 2.7: Illustration of Reflection, Refraction, Scattering, Diffraction of a Radio wave.

2.8 Error Compensation Techniques

Multipath fading introduces errors and distortions and the methods employed for compensation fall into two general categories: forward error correction and diversity techniques [12]. Typically, techniques from all two categories are combined to combat the error rates encountered in a mobile wireless environment.

2.8.1 Forward Error Correction (FEC)

This is also called channel coding where the sender adds carefully selected redundant data to its messages, also known as a forward error correcting code. The receiver is then able to detect and correct errors without asking the sender for additional data [11] [12].

2.8.2 Diversity

This involves the use of two or more communication channels with different characteristics to improve reliability. Diversity is based on the fact that individual channels experience independent fading events. The error effects can therefore be compensated for by providing multiple logical channels in between the transmitter and receiver and/or receiving multiple versions of the same signal which are then combined at the receiver [8][12]. This technique does not eliminate errors but it does reduce error rate, since the transmission has been spread out to avoid being subjected to the highest error rate that might occur. The different techniques of diversity like space, time, frequency and the basis for cooperative communication which is the focus of this thesis [10].