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PERFORMANCE ANALYSIS OF RELAY AND COMBINING METHODS IN WIRELESS NETWORKS

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ABSTRACT

The quality signal in a wireless transmission occasionally suffers from severe bad channel quality due to effects like fading caused by multi-path propagation. Diversity is one of the methods that used to reduce such effect whereby different samples of the same signal are transferred over essentially independent channels. Cooperative wireless communication it resolves this problem by transmitting a message to a destination with the assistance of a relay. Upon receiving the message from the transmission source, the relay retransmits the message to the destination. Therefore, the combination of the direct and relay transmissions, improves signal reception at the receiver whereby the signal is clearer and better. As such, this paper compares and evaluates the performance of different relays and combining methods in cooperative relay network under noisy and Rayleigh fading channel. This paper examines the Amplify and Forward (AAF) and Decode and Forward (DAF) relay protocols using Maximal-Ratio Combining (MRC), Fixed-Rate Combining (FRC) and Equal-Rate Combining (ERC) methods with BPSK and QPSK modulation based on simulations. The result of the simulations, show that AAF performs better than DAF in terms of Bit Error Rate (BER) without the introduction of error correcting code. Another finding reveals that the relative distances between the relay and the stations affect the performance of BER. The unique of this work is, presented different combining methods with different distance channels between users, distention and relay using different modulation technique. The best performance is achieved when the relay is located in the middle between the source and destination. Finally, the combination of FRC and BPSK shows the best BER performance for SNR up to 20 dB.
Keywords: *Cooperative, Relay, Diversity Protocols, Combining Methods, Fading, Path Loss.*

1. INTRODUCTION

Due to the effect of severe fading and path loss, space diversity technique is critical for wireless network to have reliable communications. One of the well-known space diversity techniques is to employ multiple transmit/receive antennas for users in the network [1]. This creates multiple transmission paths so that individual severe fading and path loss effect can be mitigated. However, due to some practical limitations, multiple antennas may not be practical to implement. An alternative solution to create space diversity is to encourage communication units with single antenna to share their resources and help each other for transmission. This can be simply described as one user "overhears" its partner's signal and "relays" it to its partner's intended destination. This signal relaying using independent path creates a virtual multiple transmit antennas effect. The earliest work of signal relaying can be traced back to Cover and El Gamal [2], in which capacity of the relay channel was derived. Laneman and Wornell [3, 4] presented some practical cooperative schemes: Amplify-and-Forward (AAF) and Decode-and-Forward (DAF). Sendonaris [5] implemented an effectively DF cooperative scheme in the code-division multiple access (CDMA) system. Later, Hunter and Nosratinia [6] proposed a new cooperative scheme in which signal relaying is integrated with channel coding design, called Coded Cooperation (CC). Both of the above cooperative schemes can achieve full diversity [4, 6]. Ref [7] gave a tutorial review of these cooperative schemes. Cooperative relay is a cooperative multiple antenna technique which exploits user diversity by decoding the combined

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signals of the relayed signal and the direct signal in wireless multi-hop networks. A conventional single hop system uses direct transmission whereby a receiver only decodes the information based on the direct signal as the relayed signal is regarded as interference. Meanwhile the cooperative relay considers the other signals as contribution; hence it decodes the information from the combination of the two signals. In short, the cooperative relay is an antenna diversity that employs distributed antennas if each node in a wireless network. As such, cooperative communication relay is differs from relay channel in various aspects. Recent developments are motivated by the concept of diversity in a fading channel, whereas primary research focused on analyze of the capacity in an additive white Gaussian noise (AWGN) channel [8, 9]. Hence, cooperative relay is more popular than relay channel. The other difference lies in the purpose.

The sole purpose of the relay channel is to assist the main channel, while the cooperation relay acts both as information sources as well as relays because all resources in the system are fixed, demonstration and comparison of these methods appears in Figure 1 illustrates a simplified.

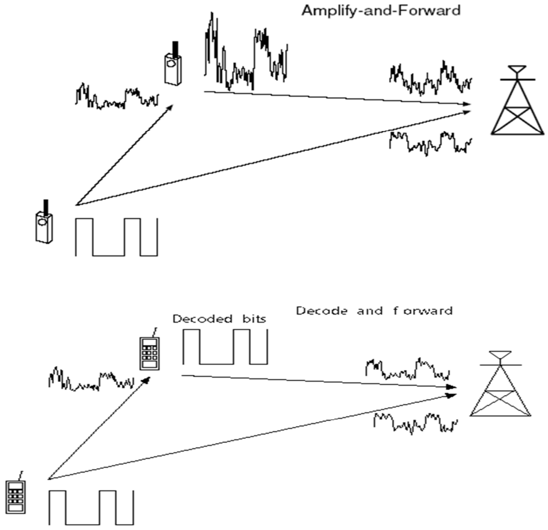

Figure0 Comparisons Of Different Cooperative Methods

It is necessary to explain the two key concepts namely cooperation and relay. Cooperation is the act of working together willingly for a common purpose or benefit. It refers to the use of two or more antennas that are separated in space so that they provide more paths to/from a source or destination. Meanwhile, relay refers to act of transmitting and receiving of information. There are two Transmission Protocols of Relay. The first one, Amplify and Forward (AAF) is a strategy that allows the relay station to amplify the received signal from the source node and to forward it to the destination station. The next one, Decode and Forward (DAF) is a strategy that allows the relay station to decode the received signal from the source node, re-encode it finally the forward it to the destination station[10].

The combinations of several relay protocols with different methods of combining them have resulted in combination such as Maximum Ratio Combine (MRC), Equal Ratio Combine (ERC) and Fixed Ratio Combine (MRC). They are examined to determine their effects on the performance of the system. The simulation carried out on this combination has proven the achievement full of diversity as was proved. The three different types of commonly used combining methods differ in the quality of the channel. The channels that contain thermal noise, Rayleigh fading and path loss use different combining methods such as MRC, ERC and FRC, and two relay protocols namely AAF, DAF. A comparison of the combinations is performed in order to identify the combination with highest performance as well as the most ideal location of the relay station. On other hand, the finding of this work is, presented different combining methods with different distance channels between users, distention and relay using different modulation technique. This information is crucial to determine the worthiness of a particular relay station [7, 11], and give as to best choice to control on the location of relay according quality of channel by changing the combination method, modulation technique and Transmission Protocols.

2. SIGNAL MODEL

Three schemes are introduced to decode the signal at the destination node. They are the direct scheme, the non-cooperative scheme, and the cooperative scheme. Except for the direct scheme, the destination node uses the relayed signal in all other schemes.

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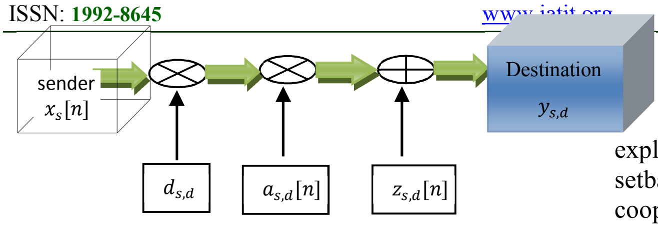

Figure 2: An Illustration Of Channel Model

Path loss $d_{s,d}$, fading $a_{s,d}$ and noise $z_{s,d}$
With $h_{d,s} = d_{s,d} \times a_{s,d}$.

2.1 Direct Scheme

In the direct scheme, the destination decodes the data from the source node using the signal received on the first phase of the transmission. The second phase of the transmission is omitted so as not to involve relay node. The decoding signal received from the source node is written as:

$$y_{s,d} = h_{s,d} \times x_s + z_{s,d} \quad (1)$$

While the advantage of the direct scheme lies in its simplicity in terms of the decoding processing, the power received signal may be severely low if the distance between the source node and the destination node is far apart. For this reason, in the following the researchers consider a non-cooperative scheme which exploits on signal relaying to improve the signal quality of the signal [10, 11].

2.2 Non-Cooperative Scheme

In the non-cooperative scheme, the destination decodes the data from the signal received from the relay in the second phase. This has resulted in the boosting of signal power boosting gain. The signal received from the relay node, which retransmits the signal received from the source node is written as:

$$y_{r,d} = h_{r,d} \times y_{s,r} + n_{r,d} = h_{r,d} \times h_{s,r}\, x_s + h_{r,d}\, n_{s,r} + n_{r,d} \quad (2)$$

where $h_{r,d}$ is the channel from the relay to the destination nodes and $n_{s,r}$ is the noise signal added to $h_{r,d}$.

The reliability of the decoding may be low for the signal relay has not increased the degree of freedom. This is the first order since this scheme exploits only the relayed signal. Because of this setback, most of the researchers consider the cooperative scheme which decodes the combined signals namely the direct and relayed signals.

2.3 Cooperative Scheme

For cooperative decoding, diversity advantage is derived when the destination node combines the two signals received from the source and the relay nodes. Figure 2.1 shows the working of a multi-hop transmission by cooperative relay.

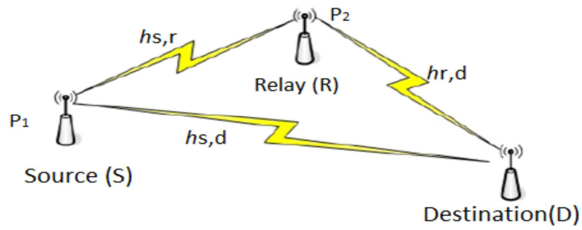

Figure 2.1 An Illustrated Concept Cooperative Relay Networks

The vector of the whole received signal at the destination node may be modeled as:

$$y_d = [y_{s,d} \quad y_{r,d}]^m = [h_{s,d} \quad h_{s,r} h_{r,d}]^m x_s + [1 \quad \sqrt{|h_{r,d}|^2 + 1}]^m n_d = h\, x_s + q n_d \quad (3)$$

where $y_{s,d}$ and $y_{r,d}$ are the signals received at the destination node from the source and relay nodes respectively [8, 12].

3. CHANNEL MODEL

The wireless relay system consists of a source, relay and destination nodes. It is assumed that the channel is in a half-duplex, an orthogonal and amplify-and-forward relaying mode. Many researchers introduce a time division relaying function to enable the delivery of information in two temporal phases for the system. This function makes the wireless relay system different from the conventional direct transmission system.

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In a wireless network, the data from a sender to a receiver has to be transmitted through the air. During transmission the signal may experience distortion due to disturbance. Therefore, in this research paper, the disturbances namely thermal noise, path loss and Rayleigh fading are given consideration.

$$Y_d[n] = h_{s,d}[n]X_s[n] + Z_{s,d}[n] = \underbrace{a_{s,d}}_{fading}\ \underbrace{d_{s,d}}_{pathloss}\ [n]X_s[n] + \underbrace{Z_{s,d}}_{noise}\ [n] \quad (4)$$

In the first phase, the source node relays information x_s toward both the destination and the relay nodes. The received signal at the destination and the relay nodes are respectively denoted as follows:-

$$y_{s,d} = h_{s,d}x_s + n_{s,d} \quad (5)$$

$$y_{s,r} = h_{s,r}x_s + n_{s,r} \quad (6)$$

$$y_{r,d} = h_{r,d}y_{s,r} + n_{s,r} = h_{s,r}h_{r,d}x_s + h_{d,r}\, n_{s,r} + n_{r,d} \quad (7)$$

where $h_{s,d}$ is the channel from the source to the destination nodes, $h_{s,r}$ is the channel from the source to the relay node, $h_{r,d}$ is the channel from the relay to the destination nodes, $n_{s,r}$ is the noise signal added to $h_{s,r}$ and $n_{s,d}$ is the noise signal added to $h_{s,d}$. During the second phase, the relay node may transmit its received signal to the destination node except in the direct transmission mode[13, 14].

4. SIGNAL NOISE RATIO

Signal-to-noise ratio (SNR or S/N) is a measure used in science and engineering to quantify the amount of corruption of a signal due to noise how much a signal has been corrupted by noise. It is defined as the ratio of signal power to the power of noise that had corrupted the signal. A ratio that has higher than 1:1 indicates more signal than noise. While SNR is commonly used for measuring electrical signals, it may be applied to any form of signal. When a measurement is digitized, the number of bits used to represent the measurement determines the maximum possible signal-to-noise ratio. This is because the minimum possible noise level is the error caused by the quantization of the signal, sometimes called Quantization noise. This noise level is non-linear and signal-dependent. There are different calculations for different signal models. Quantization noise is modeled as an analog error signal in summation with the signal before quantization (additive noise).

This theoretical maximum SNR assumes a perfect input signal. If the input signal is noisy (as is usually the case), the measurement noise may be larger than the quantization noise. There are other sources of noise in real analog-to-digital converters that further decrease the SNR in comparison to the theoretical maximum obtained from the idealized quantization noise. Although noise levels in a digital system may be expressed using SNR, it is more common to use E_b/N_o, the energy per bit per noise power spectral density [15]. The modulation error ratio (MER) is a measure of the SNR in a digitally modulated signal. It is denoted as follows:

$$SNR = \frac{s}{n} = \frac{h_{s,d}^2E^2}{N_0} = \frac{h_{s,d}^2E^2}{2\sigma^2} \quad (8)$$

5. FREE SPACE PATH LOSS

Free Space Path Loss FSPL (or path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave when it is propagated through space. Path loss is a major component in the analysis and design of the link budget of a telecommunication system. FSPL is proportional to the square of the distance between the transmitter and receiver. It is also proportional to the square of the frequency of the radio signal.

$$FSPL = \left(\frac{4\pi d}{\lambda}\right)^2 \quad (9)$$

$$\lambda = \frac{c}{f}$$

where λ is the signal wavelength (in metres), F is the signal frequency (in hertz), d is the distance from the transmitter (in meters), c is the speed of light in a vacuum, 2.99792458×10^8 meters per second.
In decibel the FSPL may be denoted as

$$FSPL = 92.44 + 20\,Log(F_{GHz} \times d_{km}) \quad \text{In dB} \quad (10)$$

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The expression for FSPL actually encompasses two effects. The first one is, the spreading out of electromagnetic energy in free space which is determined by the inverse square law.

$$P = \frac{p_t}{4\pi d}$$

where: P is the power per unit area or power spatial density (w/m^2) at distance, while P_t is the total power transmitted (in watts) [16].

The second effect is the path loss $d_{s,d}$ (assuming a plane-earth model) is proportionate to $1/R^2$. As long as the distance between the sender and receiver does not change very much, it may be assumed to be constant for the whole transmission. Therefore, the Power of the received signal is attenuated as proportional to $1/R^4$.

6. AMPLIFY AND FORWARD METHODS

Cooperative signaling employs the amplify-and-forward method. In this method, each user receives a noisy version of the signal that has been transmitted by its partner. As the name implies, the user then amplifies and retransmits this noisy version. In the base station, the information sent by the user and partner are combined before making a final decision on the transmitted bit (Figure 3). Although noise is amplified by cooperation, the base station receives two independently faded versions of the signal. This allows for the making of better decisions upon the detection of information. This method achieves the order in diversity of two, which is the best possible outcome at high SNR.
In amplify-and-forward, it is assumed that the base station knows the coefficient of inter user channel for optimal decoding. As such some mechanisms of exchanging or estimating information must be incorporated into any implementation. Another potential challenge is, the sampling, amplifying, and retransmitting of analog values is technologically nontrivial. Nevertheless, amplify-and-forward is a simple method that lends itself to analysis which is a very useful feature in furthering one's understands of cooperative communication systems.

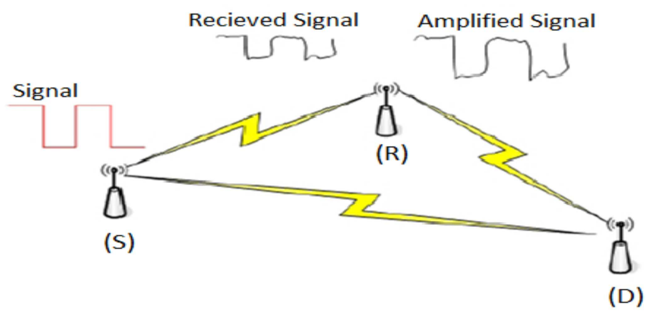

Figure 3: An illustrated the amplify and forward of the signal

7. DECODE AND FORWARD METHOD

Nowadays, the most preferred method to to process the data in relay is the use DAF. This is because most wireless transmission is analogue and the relay has enough computing power. In this method, the received signal undergoes decoded and re-encoded. So, there is no amplified noise in the sent signal as the protocol used is AAF. There are two main implementations for this system. One of these implementations occurs when the relay can decode the original message completely. This requires a lot of computing time, but it numerous advantages. One advantage is the received bit errors might be corrected at the relay station if the source message contains an error correction code. If there is no such code in the source message, a checksum allows the relay to detect for error in the received signal. Depending on the implementation, an erroneous message might not be sent to the destination. However, it is not always possible to fully decode the source message. It is not acceptable for any additional delay in the decoding and processing of the message for the relay might not have enough computing capacity or the source message requires to protection of sensitive data. In such a case, the incoming signal is just decoded and re-encoded symbol by symbol. As a result, neither an error correction can be performed nor a checksum be calculated.

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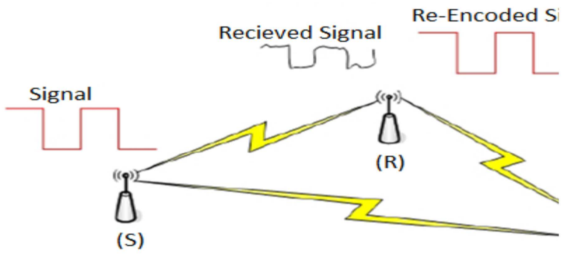

Figure 4: An illustrated for the decode and forward of the signal

8. AMPLIFY AND FORWARD TRANSMISSION

The channel during the first half of the block in cooperative relay transmission can be denoted as follows:-

$y_r[n] = h_{s;r}\, x_s[n] + z_r[n]$

Then

$y^2_r[n] = |h_{s;r}|^2 x^2_s[n] + z^2_r[n] = |h_{s;r}|^2 x^2_s[n] + 2\sigma^2_{s,r}$ (10) for n = 1 , , , ,N=4. (3.2)

Where $x_s[n]$ is the source transmitted signal and $y_r[n]$ and $y_d[n]$ are the relay and destination received signals respectively. For the second half of the block, the researcher's model led the received signal as

$y_d[n] = h_{r,d}(s)\; x_r[n] + z_d[n]$ (11)

Where $x_r[n]$ is the relay transmitted signal and $y_d[n]$ is the destination received signal. A similar setup is employed in the second half of the block, with reversal in the roles of the source and relay. Each source terminal for transmission to its destination is allocated half the degrees of freedom while communication to its relay is allocated only a quarter of the degrees of freedom. The effects of path-loss are captures by $a_{i,j}$, while the effects of receiver noise are captured by Rayleigh fading and $z_j[n]$ in the system. $h_{i;j}$ is modeled as zero-mean, independent, circularly-symmetric complex Gaussian random variables with variances $\sigma^2_{i,j}$, so that the two magnitudes, $|h_{i;j}|$ are Rayleigh distributed and ($|h_{i;j}|^2$)are exponentially distributed with mean $\sigma^2_{i,j}$). Meanwhile the phases $\measuredangle h_{i;j}$ are uniformly distributed on $[0; 2\pi)$. Furthermore, zj[n] is modeled as zero-mean mutually independent, circularly-symmetric, complex Gaussian random sequences with variance N_0.

The source terminal transmits its information as xs[n], for example n = 1; : : : ;N=4. During this interval, the relay processes $y_r[n]$, and relays the information by transmitting

$$x_r[n] = \beta \times y_r[n - N/4] \quad (12)$$

for n = N=4 + 1; : : : ;N=2. To remain within its power constraint (with high probability), compute the maximum average mutual information for amplify-and-forward transmission.

$$\begin{bmatrix} Y_d[n] \\ Y_d[n+{}^{N}/_{4}] \end{bmatrix} = \begin{bmatrix} A_{s,d(s)} \\ A_{r,d(s)}\beta A_{s,r} \end{bmatrix} X_s[n] + \begin{bmatrix} 0 & 1 & 0 \\ A_{r,d(s)}\beta & 0 & 1 \end{bmatrix} \begin{bmatrix} Z_r[n] \\ Z_d[n] \\ Z_r[n+{}^{N}/_{4}] \end{bmatrix}, \quad (13)$$

And the amplifying relay must use gain

$$\beta \le \sqrt{\frac{E}{|h_{s,r}|^2E+N_0}} = \sqrt{\frac{E}{|h_{s,r}|^2E+2\sigma^2_{s,r}}} \quad (14)$$

where E is the power of the signals, the amplifier gain depends or the fading coefficient, $h_{s;r}$ between the source and relay, with the relay estimates to high accuracy. As the term has to be calculated for every block, the channel characteristic of every single block requires being estimation. This transmission scheme may be viewed as a repetition of coding from two separate transmitters, except that the relay transmitter amplifies its own receiver noise. The destination may decode its received signal $y_d[n]$ for n = 1; : : : ;N=2. This can be performed by combining the signals from the two sub-blocks using a suitably designed matched filter (maximum-ratio combiner or equals ratio combiner or fixed ratio combiner) [9, 17].

9. DECODE AND FORWARD TRANSMISSION

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Decode-and-Forward Transmission is the most often the preferred method to process the data in the relay. The received signal is first decoded and then re-encoded. So there is no amplified noise in the sent signal, protocol used is an AAF. There are two main implementations for this system. During the first half of the block, the appropriate channel is modeled as:-

$$y_r[n] = h_{s;r}\, x_s[n] + z_r[n]$$
$$y^2_r[n] = |h_{s;r}|^2 x^2_s[n] + z^2_r[n] \quad = |h_{s;r}|^2 x^2_s[n] + 2\sigma^2_{s,r} \quad , \quad (15) \qquad \text{for } n = 1 ,,,, N{=}4.$$

where, $x_s[n]$ is the source of the transmitted signal and $y_r[n]$ and $y_d[n]$ are the relay and destination received signals, respectively. For the second half of the block, the received signal is modeled as

$$y_d[n] = h_{r,d}(s)\, x_r[n] + z_d[n] \quad (16)$$

where, $x_r[n]$ is the relays transmitted relay signal and $y_d[n]$ is the received destination signal. The source terminal transmits its information as $\hat{x}_s[n]$. For example n = 0; : : : ;N=4. During this interval, the relay processes $y_r[n]$ by decoding an estimate $x_s[n]$ as the source transmitted signal. Under a repetition coded scheme, the relay transmits the signal as:-

$$x_r[n] = \hat{x}_s[n - N/4] \quad (17)$$

For n = N/4 + 1; : : : ;N/2. Decoding at the relay may take on a variety of forms. For example, the relay might fully decode the source message by estimating code word of the source, or it might employ symbol by symbol decoding to allow the destination to perform full decoding. These options allow for trading off performance and complexity at the relay terminal, because the performance of symbol-by-symbol decoding varies with the choice of coding and modulation [4, 12].

10. CALCULATION OF THE SNR FOR BOTH TRANSMISSION LINKS

The estimation of the SNR of a multi-hop link using AAF or a direct link may be performed by sending a known symbol sequence in every block. If the multi-hop link is using a DAF protocol, the receiver may only see the quality of the channel of the last hop. It is assumed that the relay sends additional information about the quality of the unseen hops to the destination, mean that SNR of the multi-hop link may be estimated. Whichever protocol is being used, an additional sequence has to be sent to estimate the quality of the channel. However, this results in a certain loss of bandwidth.

a. Estimate SNR Using AAF

Based AAF, the received signal from the relay is

$$y_{r,d} = h_{r.d} x_r + z_{r,d} = h_{r.d}(h_{s,r} x_s + z_{s,r}) + z_{r,d}$$

The received power will then be

$$y^2_{r,d} = \beta^2 |h_{r,d}|^2 \left[|h_{s,r}|^2 E + 2\sigma^2_{s,r} \right] + 2\sigma^2_{r,d} \quad (18)$$

Hence the SNR of the one relay multi-hop link may be estimated as

$$\text{SNR} = \frac{(\beta^2 |h_{s,r}|^2 |h_{r.d}|^2 E)}{(\beta^2 |h_{r.d}|^2 2\sigma^2_{s,r} + 2\sigma^2_{r,d})} \quad (19)$$

b. Estimation of SNR Using DAF

The following describing the calculation of the SNR of a multi-hop link using DAF. First the BER of the link is calculated to be translated to an equivalent SNR. The calculation of BER over a one relay multi-hop link is follows:

$$\text{BER}_{s,r,d} = \text{BER}_{s,r}(1 - \text{BER}_{r,d}) + (1 - \text{BER}_{s,r})\text{BER}_{r,d} \quad (20)$$

For the calculation of the SNR, the inverse functions of the elements in the equation above are used.
Besides that, the SNR in case of BSPK modulated Rayleigh faded signal will be

$$\text{SNR} = \frac{1}{2}\left(Q^{-1}(\text{BER})\right)^2 \quad (21)$$
$$\text{SNR} = [\text{erfcinv}(2 \times \text{BER})]^2$$

when QPSK modulated signal is used, SNR will change to:

$$\text{SNR} = [\, Q^{-1}(\text{BER})\,]^2 \quad (22)$$

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$$SNR = [\mathrm{erfcinv}(BER)]^2$$

11. COMBINING METHODS

Different methods of combining methods are used for different type of relay protocols at destination.

a. Maximum Ratio Combining (MRC)

The Maximum Ratio Combiner (MRC) achieves the best possible performance by multiplying each input signal with its corresponding conjugated channel gain on the assumption that the phase shift and attenuation of the channel is perfectly known by the receiver.

$$y_d[n] = \sum_{i=1}^{k} h^*_{i,d}[n] \times y_{i,d}[n]$$

This equation of the one relay system may be rewritten as:

$$y_d[n] = h^*_{s,d}[n] \times y_{s,d}[n] + h^*_{r,d}[n] \times y_{r,d}[n] \quad (23)$$

A close examination of the equation reveals that a serious drawback of this combining method in a multi-hop environment. The main problem is the MRC method only considers the last hop (i.e. the last channel) of a multi-hop link. As such the MRC should only be used in combination with a DAF protocol. There is still the problem that the relay might send incorrectly detected symbols, which will have severe effects on the performance. Hence the use of MRC is only recommended if an error correcting code is used.

i. Maximum Ratio Combining (MRC)

In the decode-and-forward, MRC is used for combining the signals, after which the signal is denoted as:

$$y_d = h^*_{r,d} \cdot y_{r,d} + h^*_{s,d} \cdot y_{s,d} \quad (24)$$

Where $h_{r,d}$ and $h_{s,d}$ are the coefficients of estimated channel coefficients of channel between relay and destination, source and destination. $y_{r,d}$ and $y_{s,d}$ are the received signals from relay and source, respectively.

ii. Improved Maximum Ratio Combining (MRC)

The MRC method is used in amplify-and-forward relay. The destination combines the received signals using MRC, where the diversity combining coefficients for the two branches is as follows:

$$g_1 = h^*_{s,d} \quad (25)$$

$$g_2 = \frac{h^*_{rd}\beta^* h^*_{s,r}}{|h_{r,d}|^2|\beta|^2+1} \quad (26)$$

Which g1 is used in direct link, and g_2 is used in the link by relay together the Amplify and Forward protocol.

b. Equals Ratio Combine (ERC)

If computing time is a crucial point, or the channel quality could not be estimated, all the received signals may just be added up. This is the easiest way to combine the signals, but the performance will not be that good in return.

$$y_d[n] = \sum_{i=1}^{k} y_{i,d}$$

Since this research paper focuses on one relay station, the equation is simplified to:-

$$y_d[n] = y_{s,d}[n] + y_{r,d}[n] \quad (27)$$

where $y_{s;d}$ denotes the received signal from the sender while $yr_{;d}$ denotes the received signal from the relay.

c. Fixed Ratio Combine (FRC)

It is better to use fixed ratio combining for better performance. Instead of just adding up the incoming signals, they are weighted with a constant ratio that shows little to change throughout the whole communication. The ratio should represent the average quality of the channel; hence it does should not take account the temporary effects such as fading on the channel. But, the factors such as the distance between the different stations which change the average quality of the channel quality should be given consideration. The ratio shows only a slight change that requires only little computing

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time. Hence the FRC may be expressed as follows:

$$y_d[n] = \sum_{i=1}^{k} d_{i,d} \times y_{i,d}$$

where $d_{i,d}$ denotes weighting of the incoming signal, $y_{i,d}$. Using one relay station, the equation is simplifies to

$$y_d[n] = d_{s,d} \times y_{s,d}[n] + d_{s,r,d} \times y_{r,d}[n] \quad (28)$$

Where $d_{s,d}$ denotes the weight of the direct link and $d_{s,r,d}$ denotes one of the multi-hop links. Since this research paper selects only the best achievable performance of a FRC system, the best ratio is approximated by comparing different possible values. Later, this ratio is used for comparison of other combining methods.

12. RECEIVER SIGNALS

The receiver detects the received signal symbol by symbol. Each type of modulations is represented by a different symbol/bit. Below is a description of the different type of modulation.

a. Receive Use BPSK Modulation

The receiver detects the received signal one bit/symbol. This can be presented as follows.

$$\hat{y}_d = \begin{cases} +1 & \text{when } \operatorname{Re}(y_d) \geq 0^0 \\ -1 & \text{when } \operatorname{Re}(y_d) < 0^0 \end{cases} \quad (29)$$

b. Receive Use QPSK Modulation

The receiver detects the received signal two bit/symbol. This can be presented as follows.

$$\hat{y}_d = \begin{cases} [+1,+1] & \text{when } 0^0 \leq \measuredangle y_d < 90^0 \\ [-1,+1] & \text{when } 90^0 \leq \measuredangle y_d < 180^0 \\ [-1,-1] & \text{when } -180^0 \leq \measuredangle y_d < -90^0 \\ [+1,-1] & \text{when } -90^0 \leq \measuredangle y_d < 0^0 \end{cases} \quad (30)$$

13. BIT ERROR RATE

The quality of the signal received at the destination depends on the SNR of the channel and the method used to modulate the signal.

The same results may be obtained by simulation of the transmission using. The figures in next chapter illustrate the simulations which show the negative effects such as fading on the quality of the signal due to fading. The figures also show that the performance of the BPSK modulated signal. The findings reveal that approximate 3dB better than the one modulated with QPSK at 10^{-2} of BER. The theoretical probability of a bit error is derived.

The modulations of BPSK and QPSK are used without fading or addition of the Rayleigh fading to the equation for calculates of the BER the equation is denoted as:

I. Binary Phase Shift Keying

BPSK modulation is used to send one bit per sample.

1- Calculation of the BER with the addition of Raleigh Fading in the Channel.

$$\text{BER} = \frac{1}{2}\left(1 - \sqrt{\frac{\left(\frac{E}{2\sigma^2}\right)}{1+\left(\frac{E}{2\sigma^2}\right)}}\right) \quad (31)$$

2- Calculate the BER with ignore the Raleigh fading in the channel.

$$\text{BER} = Q(\sqrt{(E_b/\sigma^2)} \quad (32)$$

$$\text{BER} = \frac{1}{2}\operatorname{erfc}\left(\sqrt{\frac{E_b}{n_0}}\right) = \frac{0.2821}{\sqrt{E_b/n_0}} e^{-E_b/n_0} = \frac{0.2821}{\sqrt{E_b/\sigma^2}} e^{-E_b/\sigma^2}$$

II. Quadrature Phase Shift Keying

QPSK modulation is used to send two bits per sample.

a) Calculation of the BER with the addition of the Raleigh fading in the channel.

$$\text{BER} = \frac{1}{2}\left(1 - \sqrt{\frac{\left(\frac{E_b}{2\sigma^2}\right)}{2+\left(\frac{E}{2\sigma^2}\right)}}\right) \quad (33)$$

b) Calculation of the BER without the Raleigh fading in the channel.

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$$BER = Q\left(\sqrt{\frac{E_b}{n_0}}\right) = Q\left(\sqrt{\frac{E_b}{2\sigma^2}}\right)$$

$$BER = \frac{1}{2}\mathrm{erfc}\left(\sqrt{\frac{E_b}{n_0}}\right) = \frac{0.2821}{\sqrt{E_b/n_0}}\, e^{-E_b/n_0} = \frac{0.2821}{\sqrt{E_b/2\sigma^2}}\, e^{-E_b/2\sigma^2} \quad (34)$$

14. SIMULATION RESULTS

This section of the research paper is a discussion of the evaluation and comparison of the performance of (AAF) and (DAF) that have been used for different combining methods. The discussion also includes an analysis of the potential benefits of the performance of used different combination methods.

The evaluation of the performance was carried out using a simulator developed in MATLAB. There is a comparison of performance metric between Bit Error Rate (BER) and SNR. The calculation of BER is for the different relaying transmission and different combining types. The modulation schemes in consideration are (BPSK) and (QPSK).

The evaluation of the performance for AAF protocol is compared with the DAF protocol with Rayleigh fading. The finding reveals that performance of AAF is always better than that of DAF protocol.

1- Equidistant channels with Similar Channel Conditions

It is assumed that the distance from the three channels namely channel 1, channel 2 and channel 3 to three station sender, relay and destination are equal. The three combining methods (ERC), (FRC) and (MRC) are used for the comparison between AAF and DAF in Rayleigh fading.

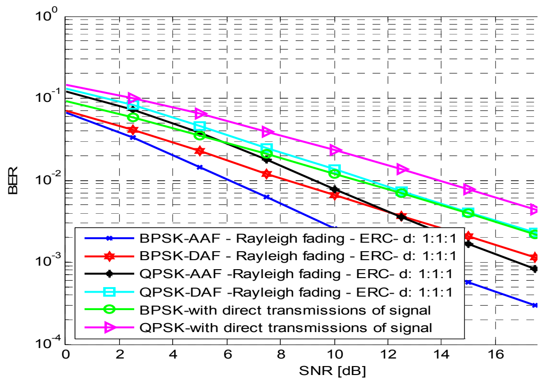

Figure 5: comparison between AAF and DAF with use of ERC

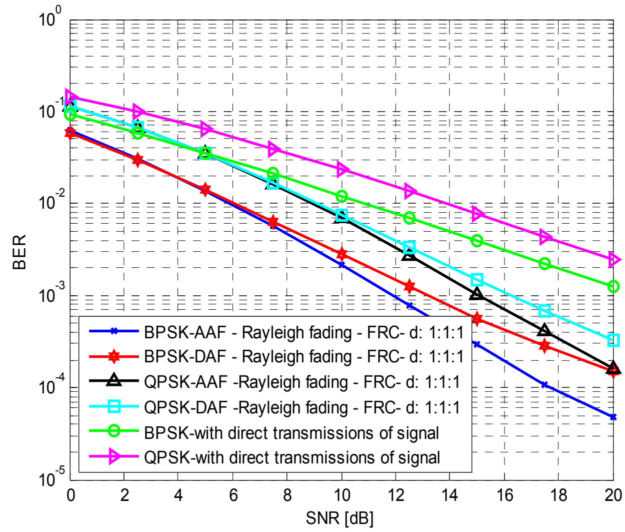

Figure 6: comparison between AAF and DAF with use of FRC

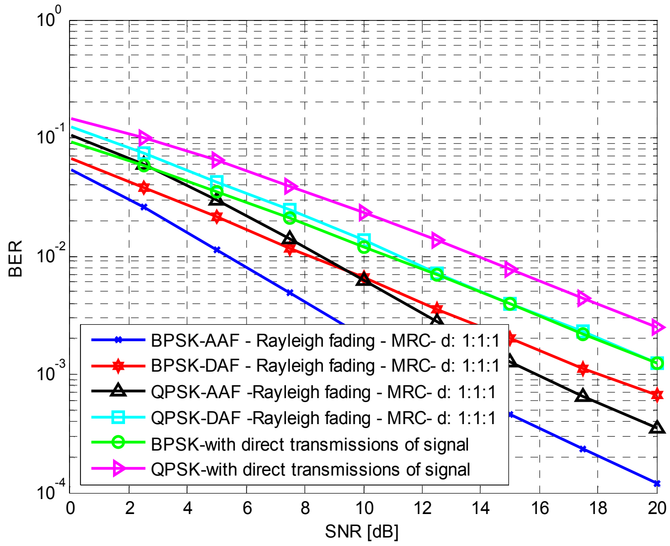

Figure 7: comparison between AAF and DAF with use of MRC

The findings in Figure 5, Figure 6 and Figure 7 compare the relay signal of the two protocols AAF and DAF with use ERC, FRC and MRC combined. It is obvious from Figure (5 , 6 and 7) that the relay signal for AAF is comparatively better than that of DAF at Bpsk and Qpsk with recordings at 2 dB,1 dB and 2.5 dB for ERC, FRC, and MRC sequentially at $10^{-2}$of BER. For DAF, the relay signal arrives in a relatively poor condition as compared to other protocols.

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Similarly, in single hop transmission, the relayed signal clearly contains more errors as compared to two hop transmission.

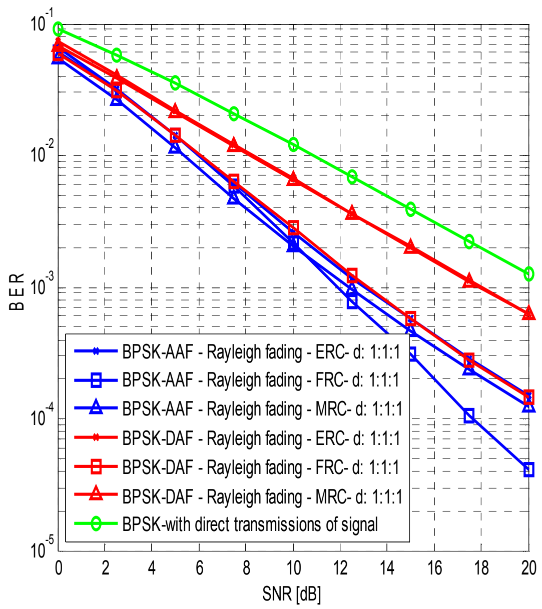

Figure 8: comparison between AAF and DAF in different Combination using BPSK in Rayleigh fading.

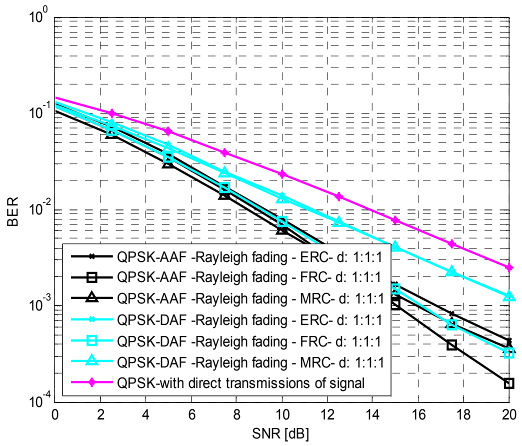

Figure 9: comparison between AAF and DAF in different Combination using BPSK in Rayleigh fading.

The Finding in Figures 8, Figures 9 indicate that AAF shows better results than DAF in any combining methods. However the best result is obtained with the use of FRC.

2- Different distance channels with Similar Channel Conditions

The second is that it is assumption is that the three channels channel 1, 2, 3 are of different distances from each other in the connection to three stations senders, relay and destination. Three combining methods ERC, FRC and MRC are used for comparison between AAF and DAF which include Rayleigh fading.

The findings Figure 10 and Figure 11 indicate that the performance of DAF approximates the performance of AAF when relay is near to the sender. However the best results are obtained when MRC combining is used with BPSK and QPSK modulation.

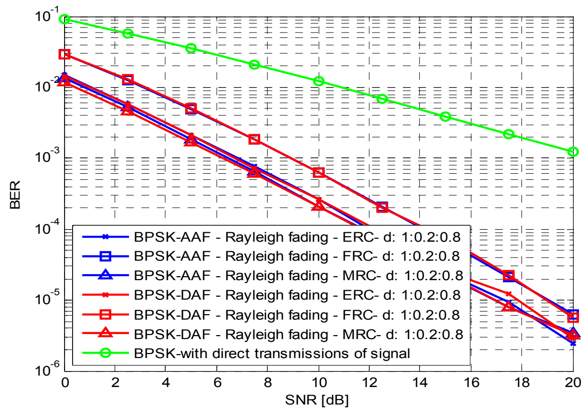

Figure 10: comparison between AAF and DAF for relay that is near to the sender and with use of BPSK.

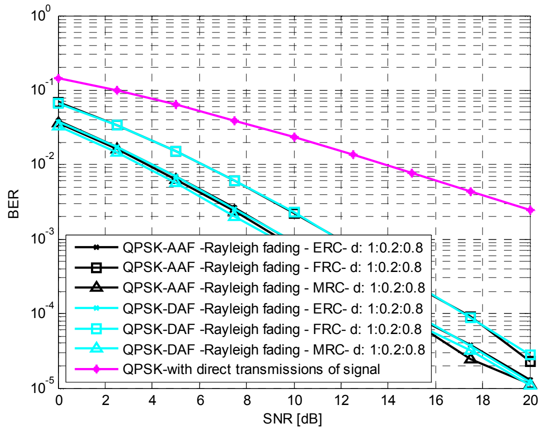

Figure 11: comparison between AAF and DAF for relay that is near to the sender and with use of QPSK.

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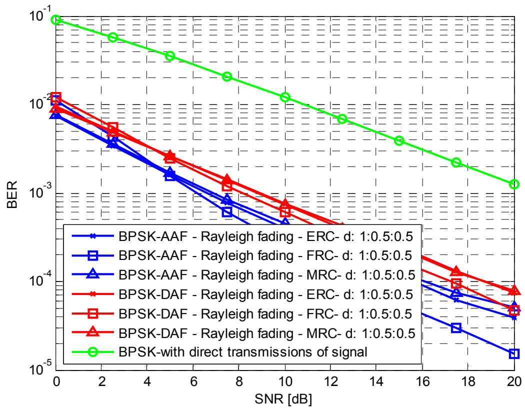

Figure 12: comparison between AAF and DAF when relay between stations and BPSK is used

The findings in Figure 12 and Figure 13 reveal that AAF better performance than DAF when relay is moved to a middle position between the sender and destination. However the best performance when FRC combined is used with BPSK and QPSK modulation.

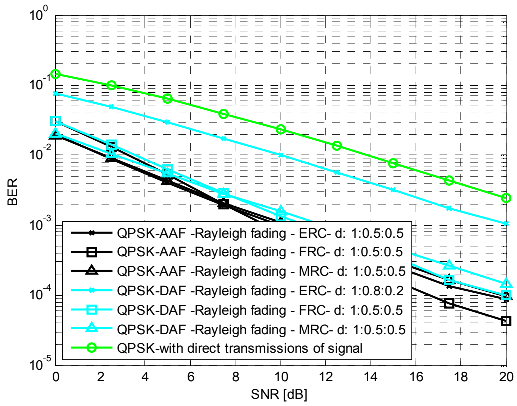

Figure 13: comparison between AAF and DAF when relay between stations and QPSK is used

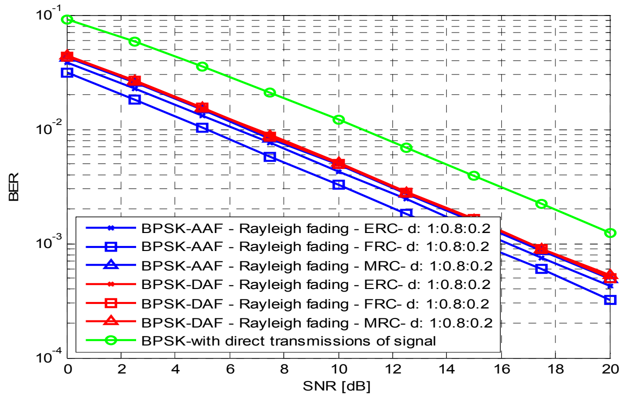

Figure 14: comparison between AAF and DAF for relay that is close to the sender and with use of BPSK.

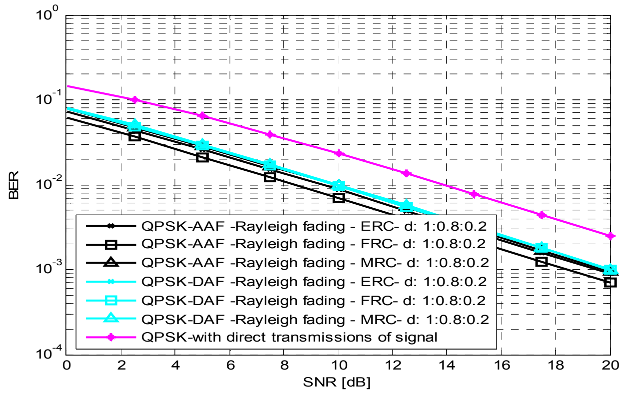

Figure 15: comparison between AAF and DAF for relay that is close to the sender and with use of QPSK

The findings in Figure 14 and Figure 15 indicate that the performance of AAF is better than that of DAF when relay is close to the destination. However the best performance is obtained when FRC combined is used with BPSK and QPSK modulation.

15. CONCLUSION AND RECOMMENDATION

This research paper has shown that a wireless transmission using cooperative relay is beneficial with to improvement in performance. The improvement is realized by building an ad-hoc network using a third station as a relay. The data is sent directly from the base or through the relay station to destination. Simulation has been carried out for different relay protocols and various combining methods. The basic idea of this cooperative relay is that a source broadcasts

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information to both the relay and the destination. Then relay retransmits the information in the same message to the destination. At the destination, the information received from both the source and the relay is combined to enhance the reliability, thereby achieving spatial diversity albeit each terminal is installed with a single antenna. The findings show that AAF protocol performs better than the DAF protocol in whatever combining methods used at the receiver. The choice of combining method has a big effect on the error rate at the receiver. When AAF is used at the relay station, it is to implement Equal Ratio Combining (ERC) compared to the single link transmission. It is recommended the use of Fixed Ratio Combining (FRC) as it this only requires knowledge of the average channel quality. Also FRC a much better performance than the ERC. If knowledge of the current state of the channel quality is available, more sophisticated combining methods may be used. The location of the relay is crucial to the performance of the best performance is only achieved when the relay is at equal distance from the sender to the destination or when the relay is slightly closer to the sender. In general, the relay should not be placed far between the two stations. The unique of this work is, presented different combining methods with different distance channels between users, distention and relay using different modulation technique, but this work doesn't take the exactly or reality distance in km and doesn't the height of relay and base station, which consider a future work to develop this work. On other hand the Doppler phenomena doesn't consider in calculation of Rayleigh channel, which is also can be a future work. Finally, the OFDM or CDMA technique can be used in sending the signal from the user and relay to the destination.

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