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Optimal Relay Selection using jellyfish Optimization Algorithm for Image Transmission over Multiuser Cooperative Communication Networks

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Fatma K. Mohamed [1]
Usama Sayed Mohamed [2]
Safwat M. Ramzy [3]

Keywords

BCH (Bose Chaudhuri, and Hocquenghem) coding; SPIHT; Cooperative network; maximum posterior decoder (MAP); Relay Selection.

Abstract

A recent study and research have shown that the relay selection schemes for cooperative communication can achieve full cooperative diversity gains and still maintains energy efficiency. Multi-source and multi-relay networks frequently cooperate to transfer their own data to the destination, mainly the access point, in cooperative wireless networks. In this paper, we use a jellyfish optimizer to select the number of relays to transmit packets of the image depending on the order of the data in the image according to its importance and at a constant rate. First, the relationships between the number of relays, peak signal-to-noise ratio (PSNR), and signal-to-noise ratio (SNR) are analysed. Second, the comparison between the performances of Equal Diversity (ED) and Unequal Diversity (UED) with Equal Error Protection (EEP) and Unequal Error Protection (UEP) is introduced using the set partitioning in hierarchical trees (SPIHT) image coder as a source coding. The jellyfish (JS) algorithm, as an efficient optimization technique, is applied for solving the problem of optimal relay selection method to reduce the bit error rate and to improve the transmitted image quality. Many useful and important results in the proposed work can be used in the enhancement of image transmission over cooperative networks. Relative to the traditional methods, the proposed method achieves better results for the transmission of images with high quality through cooperative communication networks.

1. Introduction

With the rapid growth of the Internet and the development of multimedia communications, one of the most popular data exchanges is the exchange of images. The transmission links like wireless channels normally suffer from different sources of fading [1, 2] and noise with the limited bandwidth of the transmission channels [3]. Therefore, the importance of image compression,

[1] Electrical Engineering Department, Faculty of Engineering, Sohag University, Sohag, Egypt
[2] Electrical Engineering Department, Faculty of Engineering, Assiut University, Assiut, Egypt, and Sphinx University
[3] Electrical Engineering Department, Faculty of Engineering, Sohag University, Sohag, Egypt

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image protection, and fault tolerance is a critical issue in reducing required transmission time and transmission bandwidth. The SPIHT algorithm [4] is a type of image coding, which was modified in [5] and used for image transmission through various channels with the strong transmission. Also recently, the demands for low-cost and small devices have been increasing in nascent wireless applications.

The insufficient bandwidth shared by many users and the limited battery lifetime of devices is the major reasons that motivated researchers to focus on the development of these systems. Therefore, many kinds of research have been done to improve the performance of the system, and this depends on the willingness of users to participate in the use of the resources available to them and to cooperate in the transfer of their message to each other, which is the basis of cooperative communications [6]. In [7] allow users to cooperate in transmitting each other's signal to the destination through channels with different bandwidth.

This system works on the users sharing their resources to improve the transmission quality, and this is a good and attractive thing in wireless communications due to the diversity of channel quality, bandwidth, and partial sources of energy [8, 9]. Due to fading channels that wireless communication suffer from, the signal reduction over transmission can vary considerably. Cooperative communication generates diversity which is proposed with the advantage of broadcast in a wireless medium that permits several nodes to cooperatively transmit signals to a destination together [10]. Many studies have demonstrated that cooperative communication can provide significant benefits in terms of capacity, transmission reliability, spatial diversity, and the diversity-multiplexing trade-off [11]. By using multiple-relay networks we can improve the performance of the wireless network [12].

The cooperative relay network's main idea is to mix (encode) the data that comes from multiple sources to raise the reliability at the destination of decoding [13]. Amplification and forwarding (AF), decoding, and forwarding (DF), and compression and forwarding (CF) are only some of the communication protocols available. The DF protocol is used in this paper as the communication mechanism.

The MAP for cooperative communication networks in which relay devices integrate data received from sources is proposed in [13] to construct the parity bits that are delivered to the destination.

A cooperative protocol based on the best relay selection technique is proposed in this paper. Cooperative protocols that describe relaying candidate selection [14], cooperative transmission [15], coding [16], and power distribution techniques have been the subject of several studies. In cooperative communication systems, adaptive relay selection techniques for cooperative protocols play a vital role and have a significant impact on network performance and diversity gains.

The ideal relay selected should be the best of all relaying possibilities in terms of packet outage probability and channel use efficiency [17,18], and it should be able to contribute the most to improving network performance. Because wireless networks are dynamic, the challenge of optimum relay selection is to pick the right relay in dynamic circumstances where the network topology may change, and the wireless medium is time varying. [19] presents a new relay selection method based on fuzzy logic.

In this paper we propose a relay selection scheme in the cooperative network which select number of relays for each packet depending on the minimization of distortion function and by using a JS optimization algorithm. JS optimizer is a novel optimization algorithm that mimics the behaviour and immigration of the jellyfish in the ocean [20]. The JS optimizer has been applied to solve several optimization problems where the JS optimizer is applied to determine the parameters of the

polymer exchange membrane fuel cells [21]. The authors in [22] implemented the JS optimizer to assign the parameters of the photovoltaic model.
In [23], JS has been used for optimizing the quality of service of the Elastic Optical Network (EON). In [24], the JS optimizer has been used for optimizing the random vector and in dimensional reduction of Android application features. The System Economic Load Dispatch problem has been solved efficiently using the JS optimizer [25]. In this paper, JS optimizer is used to find the best number of relays for each packet to get full diversity. A novel remote sensing satellite service can progressively implement relay cooperative transmission to realize the same frequency and common channel transmission of numerous data to conserve frequency resources. Paper [28] developed a universal model of relay cooperative channel transmission to overcome the problem of mutual interference between messages, and the separation method of heterogeneous signals for simultaneous unicast and multicast transmission is also examined. A novel model for one-way decode-and-forward (DF) based helpful image transmission in sensor networks using advanced terminologies for image compression and encryption is presented in the paper [29], and simulation results show that the proposed model outperforms state-of-the-art techniques. Also, to compare this work and demonstrate its significance, the BCH encoder suggested in [26-27] is employed in the results. The BCH Scheme was presented in [27] to select the optimal correction capabilities that provide a high-quality reconstructed picture at a given SNR.

2. Problem formulation

The challenge of transmitting an image packet without error via a relay network is described and answered in this section. Assume the image is encoded using a modified SPIHT coder [4], and the resulting bitstream is separated into packets. Let $\Delta D_i > 0$ denote the expected reduction in distortion if the packet is sent over a certain number of relays. We can write the overall distortion as pursued [4]:

$$D(L) = D_0 - \sum_{i=1}^{L} \prod_{v=1}^{i} \varphi_v(r_v)\,\Delta D_i \tag{1}$$

Where D_0 is the expected distortion when the rate is zero, $\varphi_v(r_v)$ is the probability that the $v-th$ source packet is received correctly when it is sent by a rate of r_v. L is the number of the sent packets. Let P_v be the undetected error probability of the $v-th$ packet and n_b is the number of bits in each packet. Then $\varphi_v(r_v)$ can be written as follows:

$$\varphi_v(r_v) = (1 - P_v)^{n_b} \tag{2}$$

Then (1) can be written as follows:

$$D(L) = D_0 - \sum_{i=1}^{L} \prod_{v=1}^{i} (1 - P_v)^{n_b}\,\Delta D_i \tag{3}$$

The undetected error probability of the v-th packet bit P_v is determined by the rate allocated to the $v-th$ packet r_v , as illustrated in the next section. As a result, the challenge is to minimize the expected distortion D(L) based on relay selection with a constant transmission rate. We will set the rate from the beginning to be constant and then distribute it by sending a packet over one, two, and U-relays depending on the importance of each packet (ΔD), we can formulate the problem as follows:

$$\min \underbrace{D(L)}_{u} \text{ subject to } \sum_{v=1}^{L} n_b U_v \leq R \quad (4)$$

Where R is the total transmission rate, U is the number of relays that each packet sent with, and P_v is shown in the next section.

2.1 Cooperative relay network

We examine a multiple, one-destination, access relay network with M sources and U relays [13]. As seen in Fig.1. The transmission happens in three phases. Each source is allocated an orthogonal channel (time or frequency) and sends its symbol to the destination during the first phase. Because of the wireless medium's broadcast nature, the relays likewise receive data from the sources (perhaps with some errors). Each relay node decodes the data received from the sources before encoding (linearly combining) it to produce a parity symbol. The second step, or relay selection phase, selects a number of relays to send the received data packet based on the relevance of each packet and the transmission rate. In the final phase, the selected relays send the received data packet to the destination through orthogonal channels at the same time. The destination mixes the signals from the relays and decodes the received data. It is assumed that all data is sent using a binary phase-shift keying (BPSK) modulation technique. All channels are supposed to be independent Rayleigh fading channels with additive white Gaussian noise and path loss. Let $S= [s_1, s_2\ldots\ldots, s_M, s_{M+1}\ldots\ldots., s_{M+U}]^T$ denotes the data vector sent from all sources and relays where s_1, s_2, s_M represent the sources' symbols and $s_{M+1}, s_{M+2}, \ldots., s_{M+U}$ represent the relays' symbols, $s_i \in \{+1, -1\}$, and "T" denotes the transpose. The signal received at the destination from the *i-th* (source node for $i=1, M$, and relay node for $i= (M+1,\ldots\ldots\ldots., M+U)$) is given by

$$y_i=h_i s_i \sqrt{d_i^{-z} E_i} +n_i. \quad (5)$$

and that are received at the *u-th* relay, $u=1,\ldots\ldots.,U$ from the *m-th* source, $m=1,\ldots\ldots.,M$ is given by

$$r_{um}=g_{um}\, s_m \sqrt{d_{um}^{-z} E_m} +n_{um}. \quad (6)$$

Where, h_i is the channel gain between the *i - th* node and the destination and it follows a Rayleigh distribution with $E\,[h_i^2]=1$.
d_i is the distance between the *i -th* node and the destination.
d_{um} is the distance between the *m-th* source and the *u-th* relay.
z is the path loss exponent.
E_i is the transmitted energy of the *i -th* node symbol.
g_{um} is the channel gain between the *m-th* source and the *u-th* relay and it follows

a Rayleigh distribution with $E[g_i^2] = 1$.
n_i, n_{um} is zero mean additive white Gaussian noise (AWGN) components with power spectral densities $N_0/2$ and $N_{r0}/2$, respectively.
Each relay linearly combines the decoded symbols and produces a coded (parity)

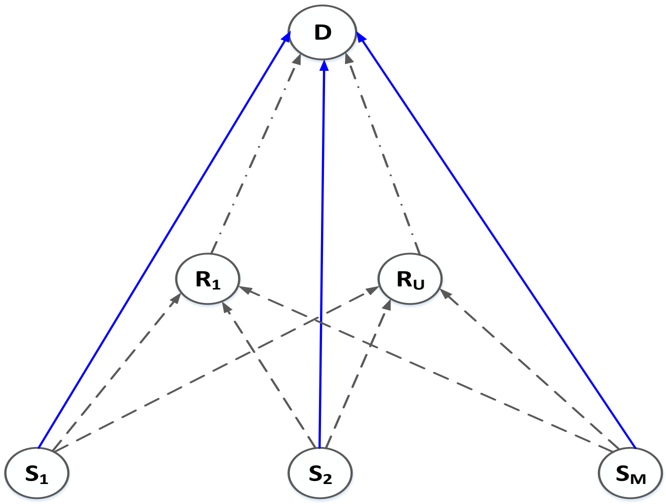


Fig. 1: M Sources, U Relays, and Single Destination Wireless Relay Network

symbol. The parity symbol generated by the *u-th* relay, $u = 1, 2, \ldots, U$ is given by

$$s_{M+u} = \bigoplus_{m=1}^{M} s_{mu} \tag{7}$$

Where s_{mu} is the decoded symbol at the *u-th* relay sent by the *m-th* source. The received signals at the destination can be written in the matrix form as follows:

$$Y = HS + N. \tag{8}$$

where the received vector $Y = [y_1, y_2, \ldots, y_{M+U}]^T$, the transmitted vector $S = [s_1, s_2, \ldots, s_{M+U}]^T$,the noise vector $N = [n_1, n_2, \ldots, n_{M+U}]^T$, and

$$H = \begin{bmatrix} h_1\sqrt{d_1^{-z} E_1} & 0 & \cdots & 0 \\ 0 & h_2\sqrt{d_2^{-z} E_2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & h_{M+U}\sqrt{d_{M+U}^{-z} E_{M+U}} \end{bmatrix} \tag{9}$$

where, $d_i^{-z} E_i / N_0 = y_i$ is the link's average received signal-to-noise (SNR) ratio from node *i* to destination.
P_v is the upper bound for the probability of error found in [13], and it is utilised to optimise the channel coding procedure later on.

2.2 Jellyfish Search optimizer (JSO) [20]

Jellyfish of all shapes, sizes, and colours may be found throughout the waters. Jellyfish have the unusual ability to seek and move around in quest of food. Some jellyfish gather their food from the water current, while others utilize their tentacles. Jellyfish are collected in swarm's dependent on conditions like as temperature, oxygen availability, and accessible nutrition. Jellyfish migrate in swarms or follow ocean currents in search of food, and they may leap or switch between these motions. JSO replicates jellyfish motions in the waters, which may be mathematically modelled as follows:

2.2.1 The ocean current

As previously mentioned, jellyfish migrate with the ocean current, which is determined by the amount of nutrients. The ocean current (Trend) direction is calculated by averaging all vectors from each ocean slit gel to the cascade gel that is now in the optimal location, which may be expressed as follows:

$$\overline{TR} = \frac{1}{n_{Pop}} \sum TR_i = \frac{1}{n_{Pop}} \sum (X_{best} - e_c X_i) = X_{best} - e_c \frac{\sum X_i}{n_{Pop}} = X_{best} - e_c \mu \quad (10)$$

$$Set\ df = e_c \mu \quad (11)$$

$$\overline{TR} = X_{best} - df \quad (12)$$

where X_{best} identifies the best site, n_{Pop} represents the number of jellyfish, e_c is the attraction control parameter, μ represents the mean value of all jellyfish sites and df returns the difference between the best solution and the mean jellyfish which is given as follows:

$$df = \beta \times \mu \times rand(0,1) \quad (13)$$

β is distribution coefficient, by replacing df of (13) to (12)

$$\overline{TR} = X_{best} - \beta \times \mu \times rand(0,1) \quad (14)$$

Can be found on the new site of the jellyfish as follows:

$$X_i(t+1) = X_i(t) + rand\ (0,1) \times \overline{TR} \quad (15)$$

By replacing $\overline{TR}$ of (14) in (15).

$$X_i(t+1) = X_i(t) + rand\ (0,1) \times (X_{best} - \beta \times \mu \times rand(0,1)) \quad (16)$$

2.2.2 The jellyfish swarm

Jellyfish motions inside the swarm are classified as passive (type A) or active (type B). Jellyfish move according to type A during the start of the swarm formation, whereas jellyfish move according to type B towards the end. The jellyfish travels randomly in passive motion as follows:

$$X_i(t+1) = X_i(t) + \gamma \times rand\ (0,1) \times (U_b - L_b) \quad (17)$$

Where L_b and U_b denote the variables' minimum and maximum bounds. $\gamma > 0$ is a motion factor. Two jellyfishes (i, j) are chosen to demonstrate active movement where $i \neq j$.When food supply is high, jellyfish i moves to jellyfish j, whereas jellyfish j moves away. The following is a representation of the active movement (movement type B):

$$X_i(t+1) = X_i(t) + \overline{ST} \tag{18}$$

where

$$\overline{ST} = rand\ (0,1) \times \overline{DR} \tag{19}$$

$$\overline{\mathrm{DR}} = \begin{cases} X_j(t) - X_i(t) \text{ if } f(X_i) \geq f(X_j) \\ X_i(t) - X_j(t) \text{ if } f(X_i) < f(X_j) \end{cases} \tag{20}$$

where f is a position X objective function.

2.2.3 Time control mechanism

The jellyfish alternates between the three motions (active motion, passive motion, and logistic map motion). The time control function (c) specifies the transmission as follows:

$$c(t) = \left| \left(1 - \frac{t}{t_{max}}\right) \times (2 \times \mathrm{rand}\ (0,1) - 1) \right| \tag{21}$$

where $c(t)$ ranges between 0 and 1. $C_0 = 0.5$ is compared to this value. When $c(t)$ exceeds C_0, the jellyfish move as a swarm, yet they follow the ocean current. It should be noted that the jellyfish's initial positions are produced at random using the logistic chaos map, as follows:

$$\xi' = \mu \xi (1 - \xi) \tag{22}$$

$$X_i(t+1) = X_i(t) + \xi' \times\ (U_b - L_b) \tag{23}$$

where ξ represents a random value produced within the range [0-1]. $\mu = 4$ and ξ' indicates the logistic chaotic value where $\xi' \neq \{0.0, 0.25, 0.75, 0.5, 1.0\}$.

In this case, JS is used to determine the optimal number of relays to send the $j-th$ image data packet through to obtain the lowest overall distortion D(L). The optimal relay selection flow chart is depicted in Fig. 2.

2.3 The proposed relay selection

In this work, we use the relay selection method that determines how many relays we need for each packet to send over to increase the performance of the cooperative network and to reduce the expected distortion D(L). So, we will recover the image correctly.

First, the transmission rate will be set to a specified value in which packets are sent with a constant number of relays. Secondly, JS Optimizer will redistribute this transmission rate to the packets according to their importance in the image.

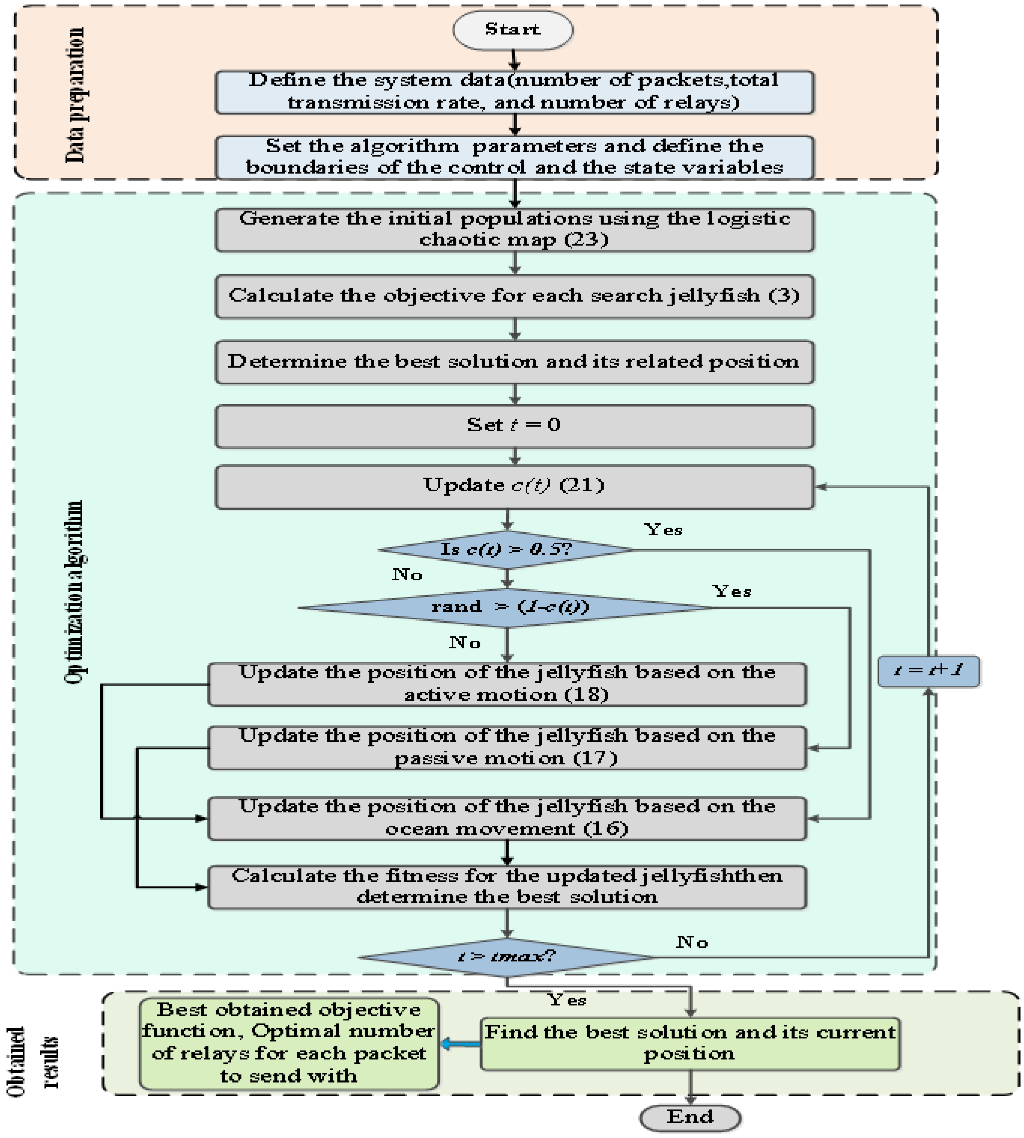


Fig .2: The Flow Chart of the Optimal Relay Selection.

3. The Proposed Scheme:

Fig.3. depicts the proposed scheme's block diagram. The image is first encoded by the modified SPIHT coder [5]. The modified SPIHT coder output is separated into four sections. Each group differentiates itself from the others based on its importance. After analysing the relevance of each packet in each group in [5] ΔD_i will be estimated for each packet in the bitstream.

The suggested scheme can be summarized as follows:

1) The SPIHT image coding technique has been changed to create four groups of bit-streams in descending order of significance, and the resultant data is then divided into a series of packets.
2) The distortion reduction ΔD_i will be approximated.
3) The Jellyfish optimization algorithm is used to create the optimum number of relays needed for each packet with a total transmission rate limit based on the number of source packets, ΔD_i of each packet, and the bit error probability of the cooperative network P_v.

4) Based on the m values for $j = 1, \ldots \ldots U$ The cooperative network distributes a number of relays for each packet based on their relevance to send a packet data via the relay network, as calculated by the optimization algorithm.
5) The MAP decoder at the destination is used to estimate the transmitted data.
6) Finally, the SPIHT decoder reconstructs the image.

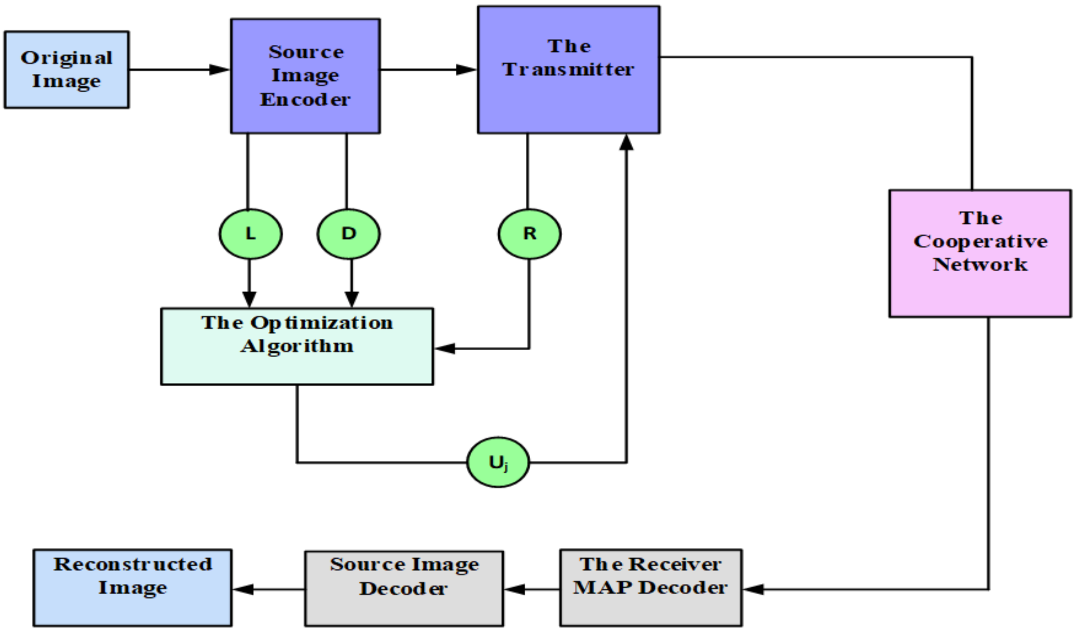


Fig. 3: The Proposed Scheme

4. Numerical results and discussions

The strategy we suggested was tested on a cooperative network with fading channels and AWGN-channel. We assumed that the mean of the square of fading gains is one. The image under examination is a 512 by 512 grayscale of the LENA image. To split the original image into sub-images, we employed the wavelet transform using a 7-tap high-pass filter and a 9-tap low-pass filter. In the wavelet domain, we only use 6 layers in the test that we propose. by using the modified SPIHT, we get a bit rate of 0.4 bit per pixel(bpp) by converting the wavelet coefficients to the source bitstream. We got four groups of source bits, and each group has been divided into a group of packets. Now we will discuss two cases:

4.1 Result of Cooperative Relay Network without Channel coder:

First, packets are sent through one and two relays at rates of 0.8 bpp and 1.2bpp, respectively, with equal diversity and varying BER and SNR, as demonstrated in the simulation results. We presented the data as a comparison of equal diversity order for all packets against unequal diversity order. Figure 4 depicts the SNR vs. average PSNR of the decoded LENA image for equal and unequal diversity. Packets transmitted through a cooperative network with the rate of 0.8 bpp. All packets in the case of ED are sent over a one-relay network with SNR = (5,10,15,20) dB. In the case of UED, each packet will be transmitted via a different number of relays according on the significance indicated by the JS optimization algorithm. In both circumstances, the overall transmission rate is the same. In the case of UED, JS optimization is used to estimate the number of relays required for each packet to be sent through in order to improve the average PSNR at different SNR. The results produced by the UED scheme outperform those obtained by the ED system, indicating the suggested method's excellent performance. Fig.5 shows the relay selection for JS's UED scheme packets. As illustrated in Fig. 5, more relays are given to the most important data at SNR =5dB, 10dB, 15dB, and 20dB. We can see that we use up to four relays in the case of the UED scheme with a rate of 0.8 bpp.

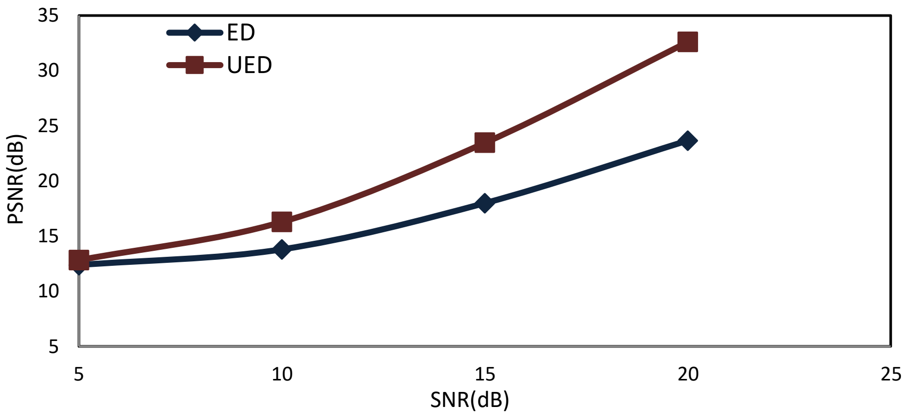


Fig. 4: Comparison between ED and UED for rate 0.8 bpp for different SNR.

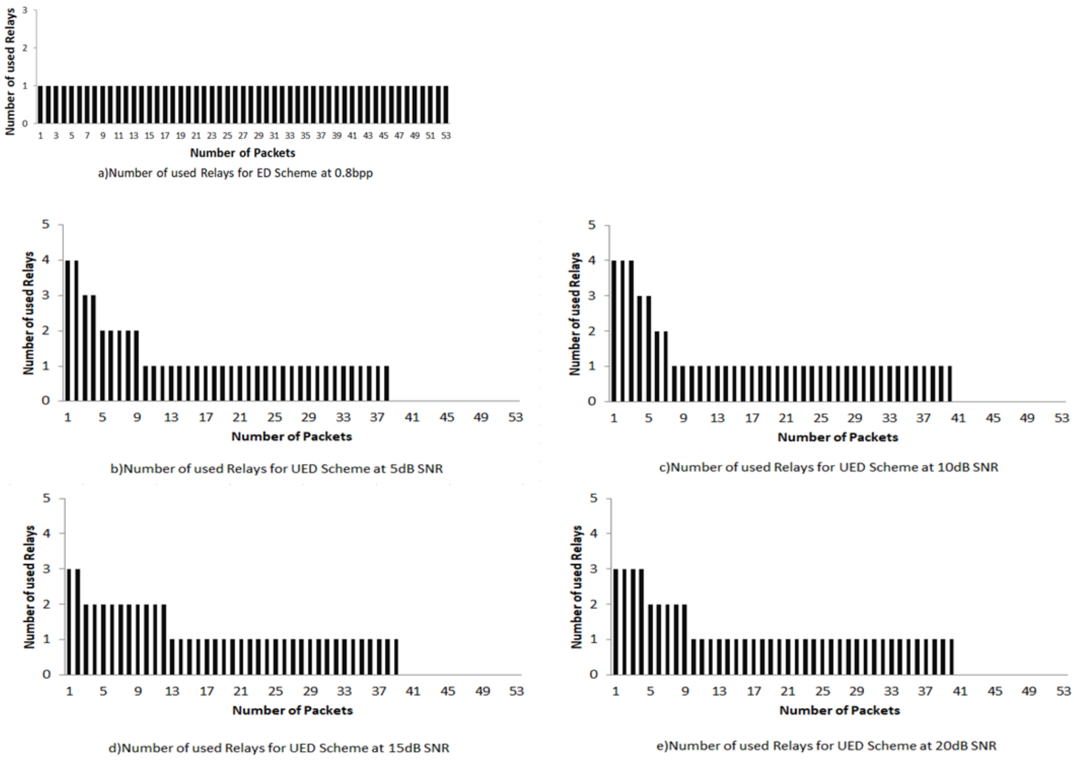


Fig. 5: Number of used Relays for UED Scheme for rate 0.8 bpp at different SNR without Channel Coder.

Fig.6 shows the different SNR as a function of the average PSNR of the decoded LENA image for ED and UED techniques when two relays are used. With equal transmission rate =1.2bpp. first, we sent packets over two relays which have equal diversity, and determine the average PSNR at different SNRs after that we sent packets with UED according to their importance as determined by the JS optimizer which shows the number of relays needed for each packet in the transmitted data but at last, sent all data with the same rate as in ED. The results produced by the UED scheme beat those obtained by the ED system, indicating the suggested method's excellent performance. Fig. 7

shows the relay selection for packets of the UED scheme produced by JS. More relays are assigned to the most significant data as shown in Fig. 7 at SNR =5dB, 10dB, 15dB, and 20dB. We can see that we use up to six relays in the case of the UED scheme with a rate of 1.2 bpp and we can see in the case of 20dB we only use up to three relays to protect important packets because we have low BER. In the last figure Fig.8. we can see the optimum number of relays that the JS choose at different SNR, and we can notice that at low SNR the JS choose high number of relays to the most significant data and the optimum relays will decrease with the increase in SNR.

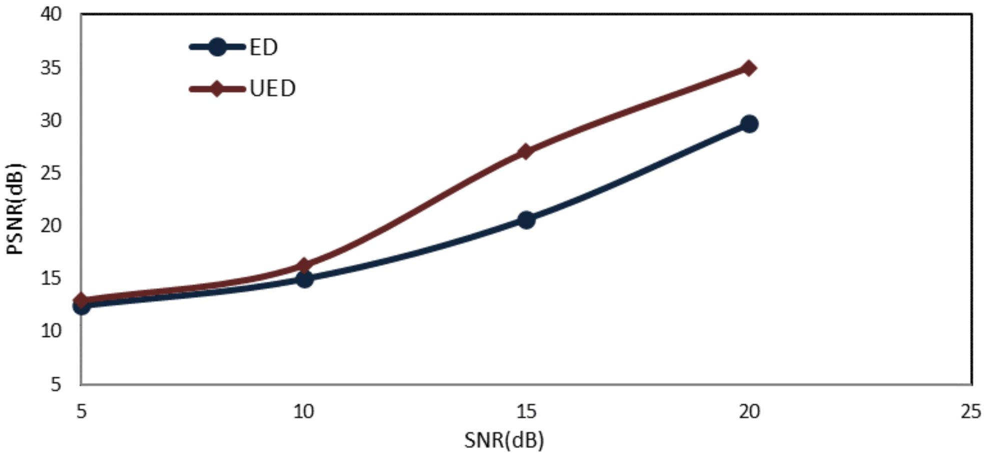


Fig. 6: Comparison between ED and UED for rate 1.22 bpp at different SNR.

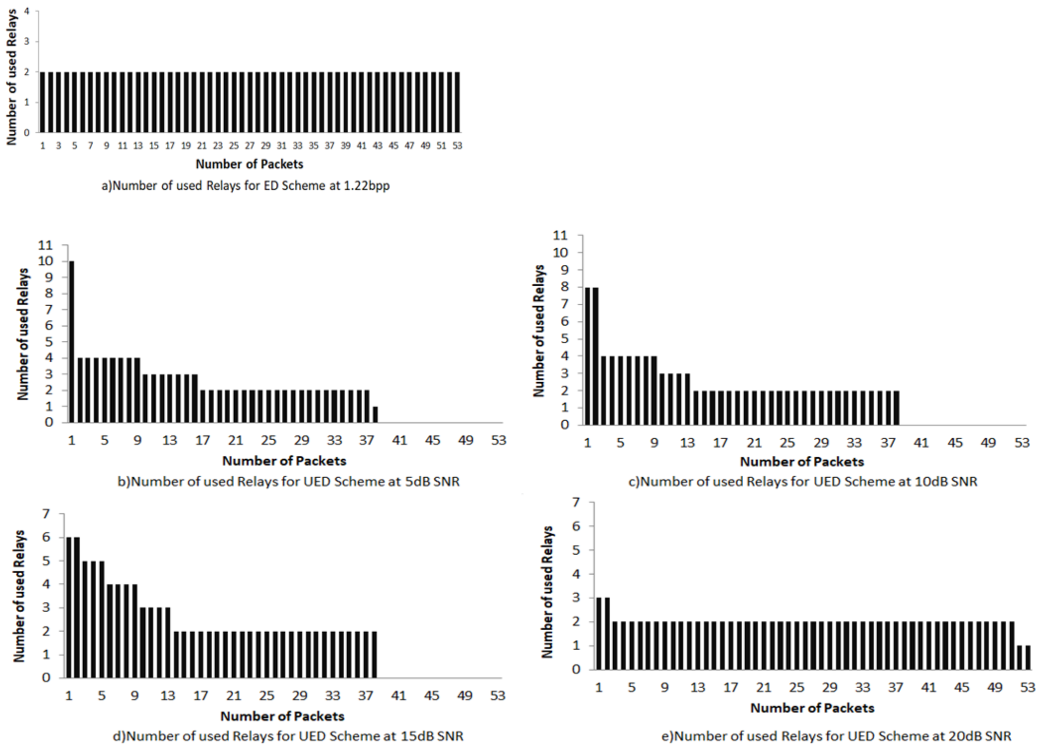


Fig. 7. Number of used Relays for UED Scheme for rate 1.22 bpp at different SNR without Channel Coder.

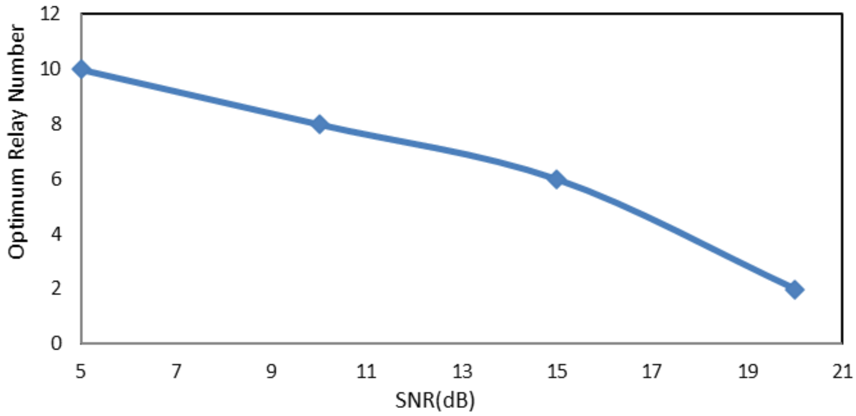


Fig. 8: Number of Optimum Relays for UED Scheme for rate 1.22 bpp at different SNR.

4.2 Result of Cooperative Relay Network with Channel coder:

Second, as illustrated in the simulation results, packets are sent via two relays with equal diversity and differing BER and SNR. We present the results in the form of a comparison between equal diversity order for all packets and unequal diversity order. Here, we employ channel coding and present the results using EEP and UEP BCH coding. Figs. 9 and 10 illustrate the average PSNR of the decoded LENA image vs the transmission rate for EEP, once with ED and once with UED. And also shows UEP with ED and UED with 5dB and 10dB SNR, respectively. Four cases are shown here, each with different rates in each figure. In the first case, EEP with ED was used, and in this case, packets were transmitted with equal protection and equal diversity. In the second case, EEP with UED is used, and packets are sent with equal protection but unequal diversity, with each packet being carried across a different number of relays according on its overall importance as evaluated by the JS optimization algorithm. in the third case, we have UEP with ED. In this case, we sent packets with equal diversity but unequal protection. The JS optimizer is used to establish the required channel coding rate rj for each packet, which assists the BCH encoder in determining the parameters required to work (n, k). Finally, the most significant case is the one where UEP and UED are used. Here, we first note that the JS optimizer was used to calculate the necessary rate for each packet to be delivered with in accordance with its importance, aiding BCH encoder in figuring out the parameters required to operate (n, k). As you can see from the above, the second state we employed is UED, where the JS optimizer will send each packet with a varied number of relays. Also, we can see at 5dB SNR we reach 97 percent of the ideal case with rate 0.5974 bpp by using UEP and UED which at this rate with neglecting noise in channel the PSNR =36.3909dB and with taking noise into our account we can reach to PSNR=35.2 dB. Consequently, the results produced by the UED and UEP schemes beat those obtained by the other instances, indicating the suggested scheme's excellent performance. Fig. 11 and Fig.12 shows the relay selection for packets of the UED scheme produced by JS in the two cases of EEP and UEP with 5dB and 10dB SNR respectively and show the different between selections in these two cases.

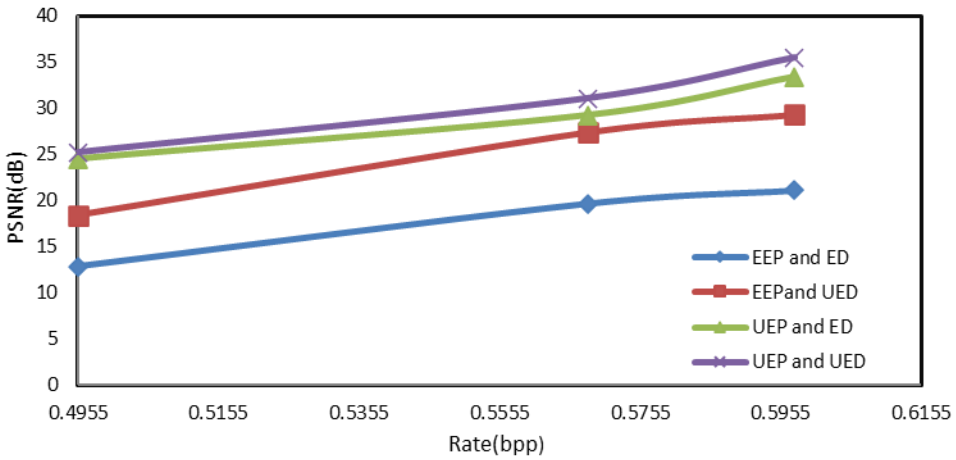


Fig. 9 Two-relay Network PSNR with an SNR of 5dB for BCH Code and Comparison between ED and UED.

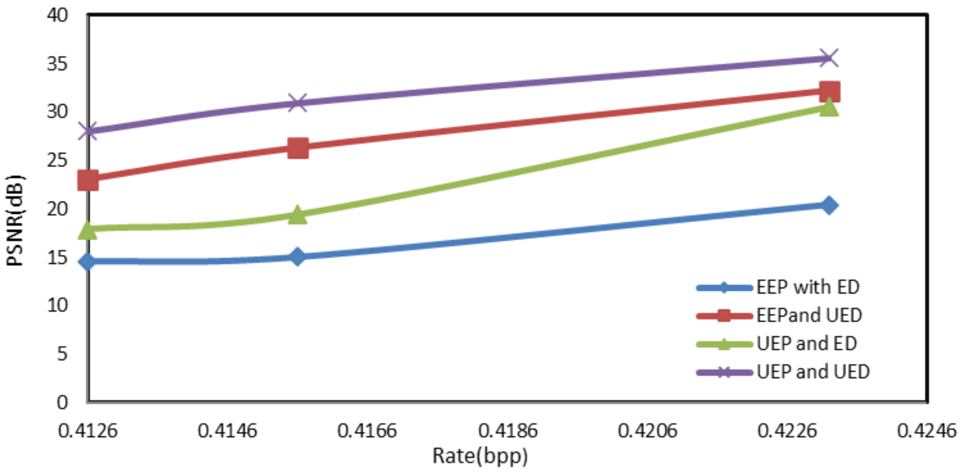
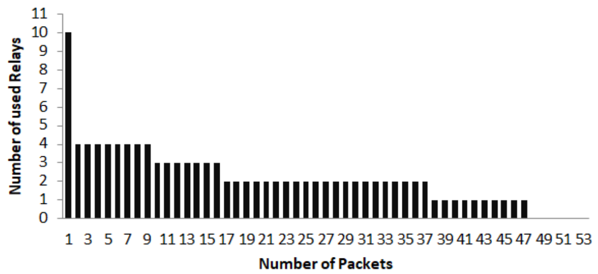
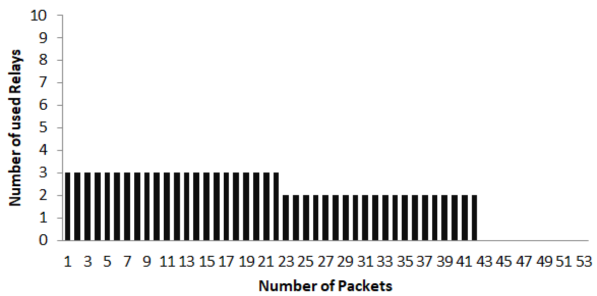


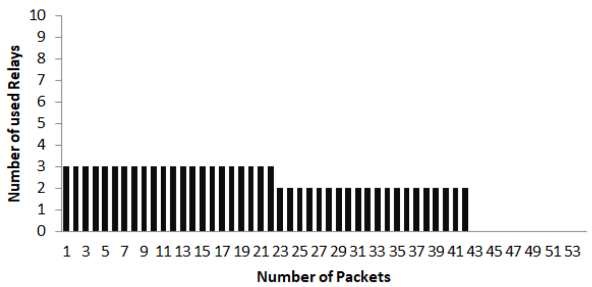
Fig. 10: Two-relay Network PSNR with an SNR of 10dB for BCH Code and Comparison between ED and UED.



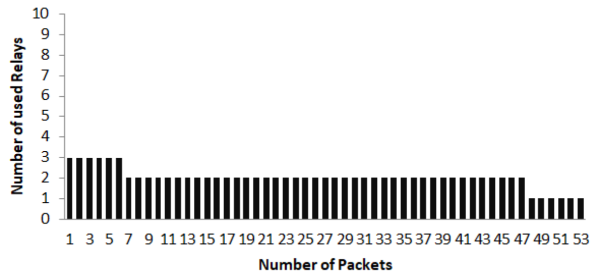
Number of used Relays for EEP and UED Scheme at rate= 0.4955 bpp



Number of used Relays for EEP and UED Scheme at rate= 0.5681 bpp



Number of used Relays for EEP and UED Scheme at rate= 0.5974 bpp



Number of used Relays for UEP and UED Scheme at rates (0.4955,0.5681,0.5974)bpp.

Fig. 11: Number of used Relays for UED Scheme at 5dB SNR for EEP and UEP BCH Channel Coder.

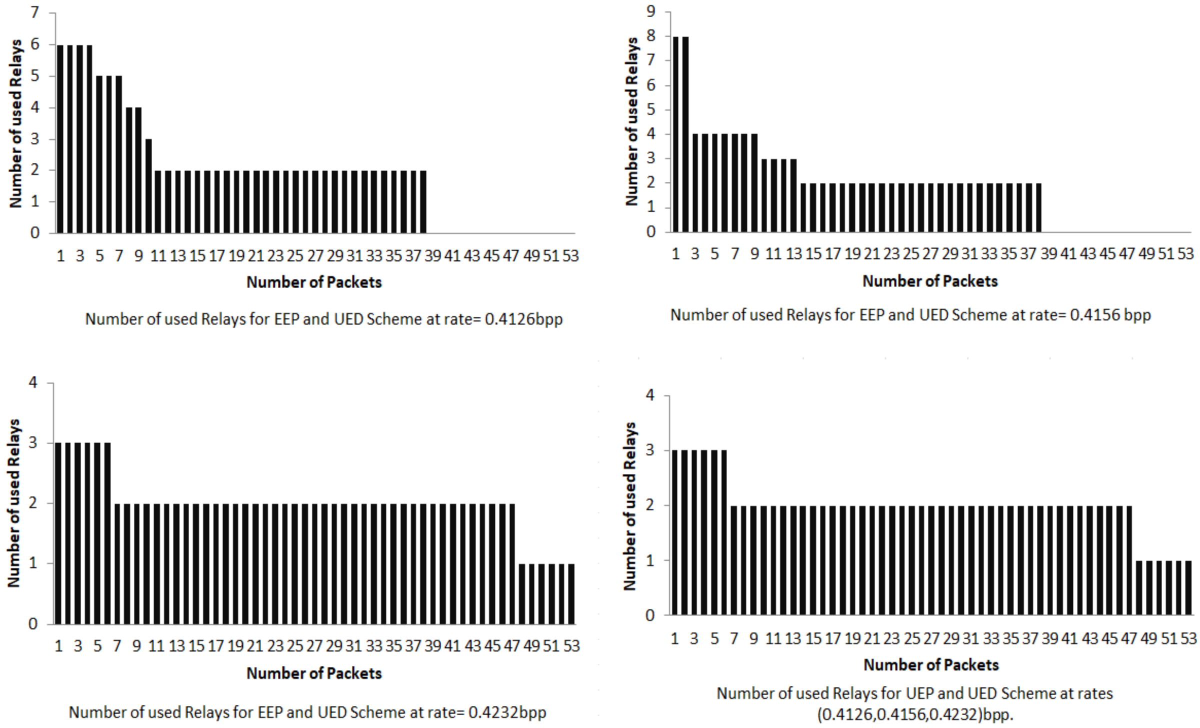


Fig. 12: Number of used Relays for UED Scheme at 10dB SNR for EEP and UEP BCH Channel Coder.

5. Conclusions

The research and analysis of relay selection for image transmission via cooperative networks is introduced in this work. The analysis system is presented for the transmission of image streams across a fading channel through a cooperative relay network.JS algorithm is applied for finding the optimum number of relays for the transmitted packets. The optimization algorithm takes as inputs the number of source packets, total transmission rate, and distortion function model. The output is a number of relays for each packet. The UED scheme is used to reduce BER of the images at different SNR and enhances the average PSNR. The simulation result shows that the performance of UED is better than ED performance at different SNR. Moreover, the results show that using BCH channel coder with the proposed scheme provides higher PSNR and decrease BER.

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