Efficient Multi-Hop One-Way Cooperative Image Transmission Over WSN

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Abstract— Toward the balance between picture quality and transmitted data intensity, the article discusses the challenges to control a high-quality image transmission over a wireless sensor network (WSN). The article proposes a novel cooperative image transmission algorithm. This article discusses the impact of a single-relay antenna array network. Our focus is on adaptive decode-and-forward (DF), whereby a relay re-transmits with an assumption of a flawless error detection code, it correctly decodes the source’s message. The proposed algorithm is applied to testbench images to test image transmission quality.

Index Terms— AF, DCT, DF, TDD, WSN

I. INTRODUCTION

Multipath fading is a significant challenge in wireless networks, and cooperative techniques such as time-, frequency-, spatial-, and antenna diversity are frequently used to mitigate its drawbacks. Collaborative wireless networks eliminate the multipath fading across multiple layers of wireless networks, introduce energy-efficient collaboration algorithms, and support various networks [1]. Networking diversity approaches are commonly used in non-ergodic settings, where Shannon capacity is not applicable; thus, diversity advantages are usually explained according to information outage probability. Cooperative diversity is an effective type of spatial diversity, but it has a multipath fading problem. Relay networks are one of these suitable diversity methods, where at the cost of algorithm complexity, power consumption, and bandwidth, a network of relay terminals provides spatial diversity. According to previous research, wireless network structures should have equal transmitters and relay antennas [2]. The relay technique is commonly utilized through timedivisionduplex (TDD) method to simplify the setup.

Source and relay are mostly communicating orthogonal signals, which may be accomplished using time multiplexing, spreading, space-time, or other coding techniques[3-5]. Although it is possible to have an orthogonality-free system, this article meets that requirement. There are two major relaying techniques: amplify-and-forward (AF) and decode-and-forward (DF). An AF relay re-transmits a magnified version of the signal without corrections nor complex judgments about the transmitted data. The fundamental cone of AF approach is that noise is present in also re-transmitted along with the data. In the traditional (non-adaptive) DF method, a relay decodes then re-transmits the signal it receives. Mitigating faulty decoded messages requires applying error detecting and correcting techniques on the received message.

In DF approach, a relay transmits chunks of the codeword via incremental redundancy rather than broadcasting the code word via repetition coding [6]. Networks having one antenna per node have been the major focus of previous cooperative diversity research, ignoring the approaches of antenna arrays at the nodes. Although the source/relay antennas in [7] form a dispersed array at the nodes transmitting space-time coded data, a node still has one antenna. In [8], two antennas at each base station are used to deliver 2-by-2 Alamouti space-time coding to a pair of phones. Each phone has only one antenna, but by exchanging information, they may function as a two-antenna receiver. Despite the fact that it is an example of a relay-networks array, the research has only considered one approach, while the option of locating the collection at a different terminal or using more than two antenna arrays should have been examined in a case generalization. In [9], the authors consistently analyzed AF techniques considering multi-antenna terminals but did not consider DF. The research in [10] examined DF techniques with a multi-antenna terminal; however, it only considered numerical analysis based on Monte Carlo integration and lacked closed-form outage probability formulation. In [11], the research explicitly studied code combining approaches for single-antenna terminal networks. In [12], the authors presented a generalization to analyze AF and DF methods and suggested another relaying, combining coding and various methods for multiple hybrid automatic repeat requests (ARQ); but only single-antenna terminals were considered.

II. BACKGROUND

A. Relaying Techniques

There are two main relaying protocols in cooperative networks in the following subsections.

1) Amplify and forward
Cooperative flagging is the amplify-and-forward strategy; as the name suggests, the client can amplify and re-transmit the got information in the noisy structure [13-18]. The base station joins the customer and some extra data and picks an end choice on the transmitted piece as Fig. 1. Despite how clarror is intensified by cooperation, the base station gets two self-ruling blurred variations of the sign and can pick better choices on the territory of data [19].

Figure 1. Amplify and forward relaying technique.

2) Decode and Forward
This arrangement is nearest to the likelihood of a standard hand-off. In this technique, a client needs to see the recipient’s bits and re-transmits the perceived bits after that [20-23], as shown in Fig. 2. The authorities may be assigned for the most part by the base station or through some other framework [24-27]. Consider two users collaborating, yet practically speaking, each client has a recipient through an extra (diversity) information way [28]. The most straightforward strategy is set methods, yet it is conceivable to accomplish a comparative impact through other alliance topologies that void the severe constraint of blending [29].

Figure 2. Decode and forward relaying technique.

B. Image compression for WSNs
WSNs with imaging abilities are highly constrained regarding memory, capacity, and power consumption due to clarror’s high probability and busyness [30]. This allows for a quick and efficient image compression computation with low memory requirements and bit rate flexibility on these frameworks [31-32]. Image processing algorithms employ numerical changes to delineate pixel respects onto multiple de-associated pixel repeats. These coefficients are then quantized and encoded. Likewise, the multi-faceted computational nature of discrete cosine transform (DCT) is not genuine DFT; thus, the DCT has become the most widely used transform coding technique [29], [30]. The 1D DCT coefficient is given by Eq. 1. Furthermore,

\[ y(k) = \theta(k) \sum_{n=0}^{N-1} x(n) \cos \left( \frac{(2n+1)k\pi}{2N} \right), \quad 0 \leq k < N - 1 \]  

\[ x(n) = \sum_{k=0}^{N-1} \theta(k) y(k) \cos \left( \frac{(2n+1)k\pi}{2N} \right), \quad 0 \leq n < N - 1 \]

Where \( \theta(0) = \frac{1}{\sqrt{N}} \) \( \theta(k) = \sqrt{\frac{2}{N}} \) for \( 1 \leq k < N - 1 \)

inverse DCT is provided by Eq. 2, respectively.

C. Wavelet Transform Image Compression
The Discrete wavelet transform (DWT) is adopted by the JPEG2000 image compression standard and is the most noticeable transform used in image coding nowadays. A channel bank includes channels, which limit the sign into rehash gatherings of the equivalent band, where a discrete sign \( x(n) \) is related to a framework including two or three-channel banks [39]. Given this sign social occasion \( x(n) \) and it is looking at z-transform \( X(z) \), a lower target sign can be gotten by low pass isolating with half band low pass channel having driven reaction \( l(n) \) with \( Z \) – transform \( L(z) \). By that point, the half-band sign can make a full band signal by downsampling by a factor of two. The “extra nuances” of the sign can be enlisted along these lines as high pass channel change of \( x(n) \) (using a channel with drive reaction \( h(n) \) and \( z \) change \( H(z) \), trailed by downsampling by a factor of two as portrayed in Fig. 6. At the less than desirable end, the sign \( x''(n) \) is reconstructed using the channel \( L''(z) \) and \( H''(z) \), individually.

D. Simulation environment and metrics
We used MATLABImage data set to examine image transmission over a cooperative wireless communication system. The experiment was conducted on a total of 65 photographs. Bit errors are when data bits change along a communication channel owing to noise, interference, distortion, or synchronization issues.

AWGN: Additive white Gaussian noise is a standard metric for random signal added in nature.

BER: Bit error rate is computed by dividing the number of faulty bits (\( N_{err} \)) by the total transmitted bits (\( N_{bits} \)) during a time interval.

\[ BER = \frac{N_{err}}{N_{bits}} \]  

MSE: Mean square error of an image data between the main image at T node to image at D node is computed as:

\[ MSE = \frac{\sum_{M} \sum_{N} [L_{T}(m,n) - L_{D}(m,n)]^2}{M-N} \]
L1 and L2 are signal source and destination nodes, respectively. **PSNR:** Peak signal-to-noise ratio denotes the rate of maximum signal power to the noise power which influences the data. The PSNR between an image transmitted from the T node to the destination D node is computed via MSE.

\[
\text{PSNR} = 10 \log_{10} \left( \frac{\text{Max}_{\text{X}}^2}{\text{MSE}} \right)
\]  

(5)

## I. METHODOLOGY

We propose a one-way image transmission technique using the proposed system design's pre-processing and image compression method. The compression method is based on the two-dimensional discrete wavelet transform (2D-DWT) approach, and the DF methodology is used for cooperative communication.

- **H1:** There is a direct relationship between energy utilization and image data transmission in WSNs.
- **H2a:** Relation between communication and energy efficiency in WSNs.
- **H2b:** Relation between cooperative communication and energy efficiency in WSNs.
- **H2c:** Relation between non-cooperative communication and energy efficiency in WSNs.
- **H3:** Relation between image denoising and image quality
- **H4:** Relation between efficient image compression and energy efficiency.
- **H5:** Relation between image compression-security and energy efficiency.
- **H6:** Relationship between different communication system models and image transmission performance in WSNs.

**Algorithm 1: Relay K(L1, L2, L3, L4)**

Inputs: Kn = K1, K2 … Ki (K Nodes)
Ln = L1, L2 … L4 (D node)
Reconstruction: T node {L1, L2, L3, L4}

FOR each Kn
Detect received blocks
IF (detect == true)
{L2, L3, L4} = FFT (Ln {2, 3, 4})
L4 = demod (Ln{1}, QPSK)
Use wavelet denoising on L4, Eq.(9)
ELSE
discard (Ln)
Break
END IF
Re-QPSK
L4 = mod (L4, QPSK)
F4 = {L1, L2, L3, L4}
AWGN {F4}

**Fig. 3:** Cooperative image transmission model

Fig. 3 shows the general architecture of the proposed cooperative digital image transmission framework. This research aims to present secure, energy-efficient, and robust agreeable image transmission over the wireless sensor systems utilizing novel techniques and techniques with different system models of communications. The key contributions are

\[
Y = HX + N
\]  

(6)

\[\text{RDF (OSR)}=\hat{f}\]  

(7)

summarized ahead. X and Y are input and output matrices, respectively; H and N are the channel and noise matrices.

Eq. (7) demonstrates the versatile; where  f refers to the decoded data at node K, and OSR presents the original data from source S to beneficiary D for capacity f_{DF}. In QPSK modulation, DF location capacity is:

\[
L^R_1 = L_1 + N_R
\]  

(9)

QPSK represents capacity reliant. We considered wavelet denoising based on square theory to cover the bustle of the picture data. This is to estiamate the NR disturbance included in L4:

Where, \(L^R_1\) is the uproarious surmise coefficient at an K node.

To cover the clamor novel hybrid method along these lines, apply the following algorithm:

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Figure 5. Sub-band decomposition filter bank using 2D-DWT

The procedure is repeated at every relay; nonetheless, the suggested benefactor receives all the image blocks. The technique of 2D-DWTA round a similar procedure can reconstruct the original picture.

III. RESULTS AND DISCUSSIONS

Fig. 6(a) shows the intensity of the image, while other sub-packs contain detailed information about the image. 6(b) exhibits one phase and two-orchestrate picture deterioration structure. Furthermore, the one-phase, two-organize wavelet deterioration of the picture ‘Barbara’ has shown up in Fig. 6(c) and 6(d). Each compressed image component is then modulated

\[ W_0(j_0, m, n) = \sqrt{\frac{1}{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \phi_{j_0, m, n}(x, y) \] (10)

\[ W_p(j, m, n) = \sqrt{\frac{1}{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \psi_{j, m, n}(x, y) \] (11)

and supplied through cooperative relay communications using the DF technique over the noisy wireless channel at the transmitter side, as shown in Fig. 8. All picture squares are received at the collector end, and the initial decompression is performed. Fig. 9 depicts the decompressed version’s output at the receiver end.
II. CONCLUSION

In this research, we designed and tested an efficient one-way cooperative image transmission in this study. The image broadcast was realized over additive white Gaussian noise (AWGN). A flexible DF technique was used to locate, unravel, re-encode, and self-assure at hand-off hubs. The BER and PSNR that resulted were compared to the grades of the previous procedures. The proposed technology increased picture spread quality dramatically and is a feasible option for secure image transmission and energy-saving applications.

I. REFERENCES


Table 1 shows a sample of photos from this data set. We assessed picture quality and data rate using metrics such as BER, PSNR, Mean Square Error (MSE), and transmission time to evaluate the exhibition of the suggested model.

Figure 9. Average PSNR ratio

Table 1. BER, PSNR, and processing time.

<table>
<thead>
<tr>
<th>Image Name</th>
<th>PSNR(dB)</th>
<th>BER</th>
<th>Time (sec.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbara</td>
<td>50.01</td>
<td>0.00231</td>
<td>0.78</td>
</tr>
<tr>
<td>Cameraman</td>
<td>37.3</td>
<td>0.0023</td>
<td>0.79</td>
</tr>
<tr>
<td>Lena</td>
<td>53.46</td>
<td>0.0024</td>
<td>0.75</td>
</tr>
<tr>
<td>Couple</td>
<td>58.58</td>
<td>0.0022</td>
<td>0.81</td>
</tr>
<tr>
<td>Man</td>
<td>58.69</td>
<td>0.0023</td>
<td>0.79</td>
</tr>
</tbody>
</table>

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