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Energy Aware Cooperative Image Transmission for Multi-Radio Multi-Hop Wireless Sensor Networks

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Abstract: A demanding job while transferring more quality images across Multi-Radio Multi-hop Wireless Sensor Network (MRMH-WSN) is to obtain good quality pictures by using less energy consumption. This work defines about a process where the cohesive image is transmitted from transmitter to the receiver of MRMH-WSN. The suggested method deals with efficient image transmission among orthogonal wireless channels with high quality of pictures and minimal error performance measurement. In this paper, we propose an Energy Aware Cooperative Image Transmission (EACIT) to minimize energy efficiency by calculating the maximum transmitting power to meet the target bit error rate in a hop and further by making use of multiple radio terminals, we improve the performance of EACIT by implementing spatial multiplexing. Simulation result shows that the proposed approach gives the better performance and saves 33% (approximately) of the energy compared to state-of-the-art algorithms.

Keywords: Multi-radio multi-hop, Wireless multimedia wireless sensor, Cooperative image transmission, Energy efficiency.

1. Introduction

Today the development of miniaturization technology provides operators to combine all hearing devices of various structures under common hearing platform. The advantage of miniaturization technology understands CMOS (Complementary Metal Oxide Semi-conductor) video camera technologies. CMOS cameras connected to WSN (Wireless Sensor Networks). This network is also named as WMSN (Wireless Multimedia Sensor network) [1-3].

WSNs (Wireless Sensors Network) have a large number of geographically distributed areas or nodes that co-examine environmental or physical conditions, with the limitations provided, such as energy of batteries, memory space and power transfer [4]. A main problem for WSN is the usage of large quantities of batteries used in node formation effects in raising power efficiency [5]. With the advantage of small power devices, the node time is detected for a longer period of inactivity. On WMSN plan, there is a need to use image processing techniques such as multidimensional methods to sensing gadgets [6]. For example, they vary from programs that support telemedicine to latest military.

WMSNs are made up of multiple multi-media sensing devices that interchange multi- media information by utilizing wireless channels to the sink. WMSNs not only transform to improve present sensory applications for example environmental monitoring and tracking, but will also activate several new types of applications [7]. For example, they vary from programs that support telemedicine to latest military. In order to meet Quality of Service (QOS) needs and to utilize rare system resources efficiently and effectively, these features of WMSN and other research issues such as area of coverage and security [8, 9].

Multimedia processing networks is one of the factors contributing to the creation of WMSNs. The design of WMSNs allows the processing of multimedia information from the environment. In multimedia networks transmitting the images which has higher quality is very demanding job. For improving the life time of network, image compression method is implemented and transmitting data over wireless sensor networks leads to packet loss and fragment reduction, hence to reduce this cooperative communication is used in [9].

Cooperative Communication (CC) allows network communication terminals to obtain and facilitate the transmission of information to each other, by taking advantage of wireless multimedia communication transmission. It can be used to improve network connectivity, increase spectrum power and efficiency, and improve communication reliability. Moreover, in comparison to other emerging strategies that can achieve the same performance benefits, such as the multiple-input-multiple-output (MIMO) technique, cooperative communication is superior in flexibility and hardware performance. Further CC technique is extended to High Frequency (HF) radio, Device to Device (D2D) communication and large scale Mobile Ad hoc Networks (MANETs) to improve the network performance. Cooperative routing algorithms are cross layer approaches, formulated by combining the cooperative communication and routing at physical layer and network layer respectively.

In cooperative wireless multimedia communications, we are concerned about a wireless, cellular or commercial network, in which wireless agents, whom we call users can increase their service quality level (measured by physical layer by small error rates and blocking error rates) through cooperation. In a cooperative communication system, every wireless user is considered to transmit multimedia information and act as a co-operative agent of another user.

While transmitting large quality pictures over wireless sensor networks leads to loss in the characteristics of picture [10, 11]. At node by use of encoding and decoding process energy consumption is more. Energy efficient image transmission in MRMH-WSNs is pioneer solution for more energy consumption. A novel method of energy saving cooperative image transferring in wireless multimedia networks to improve the performance of the network, enhancing the quality of an image and also in order to reduce the energy consumption. Energy Aware Cooperative Image Transmission processes is divided into two stages. Stage 2 is our main work.

- In stage 1, when a new flow request arrives from the source node, a cooperative routing path is established between source and destination as illustrated in [12].
- In stage 2, source node obtains the maximum power required to transmit the image to meet the target bit error rate and making use of multiple radio terminal spatial multiplexing is implemented to further improve the performance of the MRMH-WSN.

The rest of the paper is organized as follows. In Section 2, we presented related works. Our system model and energy aware cooperative image transmission approach is presented in Section 3 and 4 respectively. Section 5 gives the simulation results of proposed approach and finally we concluded our paper in Section 6.

2. Related work

Image transmission over Multi-hop wireless networks has sparked a lot of interest in the academic community, and several studies have been conducted to improve network performance. Lecuire et al. [6] suggested image transfer by looking at WSN power efficiency. Two different methods were designed as open loop method and closed loop method. These methods were developed over wavelet image modification and reliable transformation to achieve energy saving. Wavelet image modification properties information break-down in various stages of resolution. So the image can separate by packets while transferring via collaborative communications.

In [2], the authors suggested an efficient image transmission strategy that focuses on relayed picture transmission across wireless channels with the best image quality and bit error rate performance. First, as photos acquired under diverse lighting situations, a lightweight image quality enhancement mechanism was developed at both the transmitter and receiver end. Second, the suggested compressive sensing was implemented utilizing the 2D discrete wavelet transform's approximation coefficient. By proposing the hybrid thresholding function, we took use of the wavelet de-noising advantage. Finally, at relay nodes, the decode–

forward technique is used to decode and forward incoming image data blocks. According to the standard orthogonal frequency division multiplexing model, the compressed approximation component of the 2D discrete wavelet Transform is used to apply the inverse fast Fourier transform and then in modulation using quadrature phase shift keying to transmit over additive white Gaussian noise channel to relay nodes.

Wei et al. [4] established assignment based on a picture-pixel position strategy to enhance the level of image conversion is compatible with complete restriction of the power allocation of image requests to WMSN. Network resources are well allocated for PHY, MAC, and APP layers of into-segment state are guaranteed if image conversion rate has improved. The outcomes for this the article sought the help of a quiet approach for achieving the best image quality and power capacity.

Honggang et al. [5] suggested cooperation conversion scheme for converting picture sensors in succession using an intra sensor communication for modification and security in the distribution of models developed in path diversity. Secure picture transfer and energy capacity were a remarkable presentation by the author. This strategy did not allow for all images the sensor for transmitting the appropriate pieces of images combined with an active transform the tracks are properly powered, but also offer different savings of aligned image areas with track preferences and BER is required.

For WMSN, in [9] authors have been provided a unique article vision replica as well as an image transform approach. The transformation of an image fragment into the whole image was used in this method. It ensures that node power is conserved and that picture data is transformed as little as possible to the destination node. The proposed technique was founded on in-node power utilization and redesigned PSNR.

High transmission rates, throughput, and a low Bit Error Rate are required for high-quality picture transmission through smart devices (BER). At the same time, for battery-powered smart gadgets such as smartphones and tablets, energy efficiency is always a major concern. An adaptive Forward Error Correction (FEC) coding and cooperative relayed image transmission system is suggested in [13], which can guarantee both transmission quality and energy efficiency in a complicated mobile communication channel environment.

Tao et al. [14] presents the mechanism for determining the development of a cooperative signal to achieve powerful image conversion in WSNs. The suggestion to improve the signal was convincing due to it was able to split power consumption by extending all conversion uses different senses. Individual packets define a fixed wavelet encrypted the image presents a different contribution to the image-level direction. Influenced by this reality, they set up the right process selecting the number of cohesive sensors in all flexible packets sequence to get the best image that means limited change power allocation.

Based on image pre-processing, wavelet-based two-dimensional discrete wavelet transform (2D-DWT) methodology, and decode-and-forward (DF) algorithm at relay nodes, an energy-efficient and quality-aware multi-hop one-way cooperative image transmission framework was presented in [15]. However, there are a few more challenges to consider when managing excellent image transmission in WSNs, such as high vitality consumption when preparing to transmit an image, and achieving the balance between picture quality and image sent intensity. Real-time picture transmission via a multimode fibre (MMF) is still a difficult research project. The whole complex field of the MMF is measured and controlled in one approach [16], which completes picture transmission. In [17], authors have been proposed a family of riteless codes that may provide unequal error protection (UEP) property and equal water-fall region performance to increase picture data transmission efficiency in satellite communication systems.

In conclusion, numerous image transmission schemes are developed for energy efficient image transmission by compressing the image using DWT. For the reconstruction, all the nodes should perform post processing (enhancement) operation to improve image quality, which intern increase the energy consumption of the node. The objective of our work is to applying the spatial multiplexing by make use of multiple radio terminals for better visual quality of the picture and optimal power allocation to minimize the energy consumption.

3. System model

In this paper we modified efficient cooperative image transmission in one-way multi-hop sensor network [1] to improve the energy consumption. Consider a Cooperative Multi-Radio Multi-hop Wireless Sensor Network as shown in figure 1, where N nodes are uniformly distributed over an area of $L \times L\, m^2$. Every node in the network is assumed to be self-organized and employs the Amplify and Forward (AF) relay protocol. Assume that each node in the network contains K radio

Table 1. Summary of notations

Symbol	Description
N	Number of mobile nodes
P	Transmit Power
R	Transmission Coverage area
r	Transmission radius
P_e	Probability of error
R_i	Nodes in the transmission region of node i
M	Number of Orthogonal Channels
K	Number of radio terminals
S_{AF}	Amplification factor
$H_{l,j}$	Rayleigh channel fading coefficient
n_i	AWGN noises with zero mean
T_V	Symbol period
α	transmission efficiency
b	Bit rate
d_{ij}	distance between the node i and j
G_{Tx} and G_{Rx}	Gain factors of transmitter and receiver
M_l	Link margin
N_f	noise figure

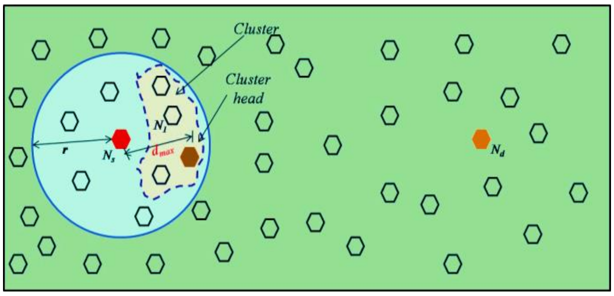

Figure. 1 Large scale cooperative network

terminals, M orthogonal channels $CH = \{ch_1, ch_2, \ldots \ldots, ch_M,\}$; a power control mechanism, which changes the transmission power based on the distance. R and r denote the transmission coverage area and transmission radius respectively and R_i is the nodes in the transmission region of node i (N_i) which can communicate directly with a probability of error P_e less than or equal to a predefined threshold.

Let the node i transmit the data to the next hop node (j) through a cooperative node (l) the received information at node j is given as [18, 19].

$$Y_{i,j} = \sqrt{P} H_{i,j}^{*} S_{AF} + n_i \tag{1}$$

$$Y_{l,j} = \sqrt{P} H_{l,j}^{*} S_{AF} + n_l \tag{2}$$

Here $S_{AF} = \left(\frac{Y_{s,r} H_{s,r}^{*}}{\sqrt{P_r}\,|H_{s,r}|^2}\right)$ intensifies the data, P is the energy transferred at the relay point, $H_{i,j}$ is the rayleigh fading channel variable of destination connection, $H_{l,j}$ is the rayleigh channel fading coefficient, S_{AF} is the re-encoded signal at the relay and n_i, n_l are the AWGN noises with zero mean and variance as 1 at destination and eavesdropper respectively.

Internal function of transmitting and receiving node in the proposed Energy Aware Cooperative Image Transmission for Multi-Radio Multi-Hop Cooperative Wireless Sensor Network is presented in Fig. 1. At the transmitter image quality improvement is performed first then followed by the image compression, in order to reduce the energy utilization without changing the picture quality. At last modulation is performed on the spatial multiplexed image and then transmitted through a wireless channel.

3.1 Pre-processing

The objective of this method is improving the picture information which put downs the unwanted disturbances or enhances few image characteristics which are major for next processing.

Laplacian filter is basically gaussian smooth filtering performed on a picture that has initially gets smoothed with approximating filter called as to decreases the noise sensitivity, and the two variables are explained together. Where $L(x, y)$ defines Laplacian filter and $I(x, y)$ defines the intensity rate. It is an edge detector [14, 20].

$$L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \tag{3}$$

Average filtering is a method of 'smoothing' images by reducing the amount of intensity variation between neighbouring pixels. The outputs of laplacian and average filters are subtracted to obtain the eventual pre-processed picture. After pre-processing, the image undergoes image compression method using 2D-DWT.

3.2 Discrete wavelet transform

Images are 2D (two dimensional) information. To convert images into 2D wavelets are used or apply the 1D transformation to the columns and rows of the picture consecutively as separable 2D transform. Calculating the coefficients of wavelet in all possible measurements produces a lot of data [21, 22]. Based on the strength of '2' the scales and locations are called dyadic scales and locations it is preferred that the analysis is more effective and exact. The analysis initializes from signal s and results in coefficients C (a, b) [23].

$$C(a, b) = C(j, k) = \sum_{n \epsilon z} s(n) g_{j,k}(n) \tag{4}$$

3.3 Modulation

Modulation is the process of varying more than one structural format for a specific time period, known as a carrier signal, with a separate signal called a variable signal that has the data to be transmitted. In OFDM, subcarrier frequency is selected such a way that they are orthogonal to each other, which means that the crosstalk between sub-channels is removed and the bands of the inter-carrier are not necessary. Orthogonality needs the subcarrier space to be

$$\triangle f = \frac{k}{T_V} \tag{5}$$

It is measured in terms of hertz, where T_V seconds in symbol period and positive integer is denoted by k, typically equal to 1. The orthogonality permits for effective modulator and demodulator implements the FFT algorithm on the receiver side, and IFFT on the transmitter side [24]. The Fourier evaluation is fundamental step utilized to transform the picture from its original zone to a deception in the time or frequency domain and vice-versa. The IFFT equation is given by

$$x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k)\, e^{i2\pi n^{k}/_{N}} \tag{6}$$

After the wireless transmission of the image with help of intermediate nodes, the image is applied to the demodulator block. Demodulation defines about extracting the original signal that carries data from a modulated wave. It is applicable to acquire best quality of original pictures from the compressed position where it requires that the quality of the picture is large whether it may be of larger size. The conversion from spatial to frequency domain, in frequency domain the basis for many image filters used to remove audio, sharpen an image, analyze repeating patterns, or extract features.

The main aim of the image de-compression is to decode an image and reconstructing the original picture. It is applicable to acquire best quality of original pictures from the compressed position where it requires that the quality of the picture is large whether it may be of larger size. Post processing is the operation of editing information captured by the visual camera when capturing a picture to enhance the picture. After the post-processing, the desired image is obtained with good quality of image and with less energy consumption.

4. Energy aware cooperative image transmission

In this paper, we presented an Energy Aware Cooperative Image Transmission scheme for multi-radio multi-hop cooperative wireless networks. Spatial diversity can be obtained in multi-radio multi hop cooperative wireless network, since each node is equipped with multiple radios. The routing path between source and destination is calculated by using cluster based hybrid multi-hop cooperative routing algorithm proposed in [12]. After calculating the route from source to destination to minimize the energy consumption, spatial diversity is implemented by using multiple radio (K) terminals. Since the maximum transmit power of each node isP_t, the power control unit will distribute the power equally among K radio terminals, i.e., each radio terminal is allowed to transmit with the power $\frac{P_t}{K}$.

The amount of energy consumed per bit for $i$to j transmission (i.e., per hopE_h) is given by [12, 25, 26]

$$E_h = \sum_{i=1}^{H} (1+\alpha) \left({}^{P_t}/_{K} \right) Q\left(d_{ij}\right)^n M_l N_f + \frac{P_{Tx}+P_{Rx}}{b} \tag{7}$$

Where $Q = \frac{(4\pi)^n}{G_{Tx} G_{Rx} \lambda^2}$; b is the bit rate, α $(= \frac{\zeta}{\xi} - 1)$ is the transmission efficiency of a power amplifier which depends on the modulation. For MQAM $\zeta = 3 \frac{2^{\frac{b}{2}-1}}{2^{\frac{b}{2}+1}}$, d_{ij} is the is the distance between the node i and j, G_{Tx} and G_{Rx} are the gain factors of transmitter and receiver respectively, n is the path loss exponent, M_l is the Link margin, N_f is the noise figure and, P_{Tx} and P_{Rx} are the transmitter and receiver circuit powers respectively. The total energy consumption of a path from source to destination can be obtained by adding energy consumption of each hop.

In order to minimize energy consumption, we have suggested an Energy-Efficient Transmission scheme where the transmission power of a node can be minimized (less than P_t) in order to meet the BER P_b target. The maximum transmitting power P needed to accomplish the target BER shall be obtained by the Chernoff bound.

$$P \le \frac{K N_0}{P_b^{\,1/K}} \tag{8}$$

Where $P < P_t$

Table 2. Simulation parameters

Parameter	Quantity
Number of Nodes	200
Number of Orthogonal Channels	10
Number of Radio Terminals	2
Maximum Transmit Power	1W
Noise Variance	10^{-10}
Link Margin	40dB
Noise Figure	10dB
Transmitter and Receiver gain	5dB
Target bit error rate	10^{-3}

5. Simulation results

The simulation is carried out using MATLAB software with the simulation parameters given in Table 2. The proposed method is applied on five different images which give comparison between the direct transmitted image, and two previous proposed approaches.

The PSNR is often used to measure the quality of picture and video reconstruction in terms of lost compression. Mean Square Error indicates the cumulative squared error between the compressed and the original picture.

$$PSNR = 10log_{10}\left(\frac{Max_I^2}{MSE}\right)$$

$$PSNR = 20log_{10}\left(\frac{Max_I}{\sqrt{MSE}}\right) \quad (9)$$

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1} f(i,j) - g(i,j)^2 \quad (10)$$

Where f defines the original image, g is degraded image, is the number of pixels of picture and I indicates the index of that particular row, n is number of columns of pixels and j indicates the index of that column. The SSIM is computed on different parts of a picture. The quantity between x window and y window is of the same size *N*×*N*

$$SSIM(x,y) = \frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \quad (11)$$

μ_x is the average of x, μ_y is the average of y, σ_x^2 is the variance of x, σ_y^2 is the variance of y, σ_{xy} is the covariance of x and y.

The comparative analysis of proposed approach in terms of PSNR (peak signal to noise ratio) over various state-of-the-art approaches are presented in Table 4. For a cameraman image, in direct transmission is of value 12.1391dB, for previous approach of Yasar resulted in 20.4784 dB and Bilal's approach gained 26.8140dB and this proposed work

Table 4. Peak signal to noise comparative results

Image Name	Sara Taher Abbas et al [15]	Yasar et al [8]	Bilal et al [2]	Proposed
Cameraman	27.139	20.478	26.814	30.029
Lena	27.583	20.526	26.798	30.284
Circuit	26.137	19.143	25.520	28.823
Bags	25.676	18.703	25.094	28.583
AT	27.4760	20.701	27.029	30.099

Table 5. Structural similarity index comparative results

Image Name	Sara Taher Abbas et al [15]	Yasar et al [8]	Bilal et al [2]	Proposed
Cameraman	0.7764	0.4380	0.7617	0.8662
Lena	0.7705	0.4488	0.7657	0.8778
Circuit	0.7996	0.4205	0.7798	0.8859
Bags	0.8639	0.5955	0.8577	0.9295
AT	0.6775	0.2827	0.6668	0.8167

Table 6. Mean square error comparative results

Image Name	Sara Taher Abbas et al [15]	Yasar et al [8]	Bilal et al [2]	Proposed
Cameraman	134.584	582.427	135.418	64.584
Lena	134.516	575.995	135.919	60.901
Circuit	181.144	792.103	182.398	85.265
Bags	200.572	876.477	201.221	90.093
AT	127.491	553.280	128.867	63.558

obtained PSNR value of 30.0295dB hence, higher the PSNR, the better the quality of the reconstructed image.

The comparative analysis of proposed approach in terms of Structural similarity Index (SSI) over various state-of-the-art approaches are presented in Table 5. For a cameraman image the direct transmission is of value 0.1164, for previous approach of Yasar resulted in 0.4380 and Bilal's approach gained 0.7617 and this proposed work obtained PSNR value of 0.8662 hence, higher the SSIM good quality reconstruction.

The comparative analysis of proposed approach in terms of Mean Square Error (MSE) over various state-of-the-art approaches are presented in Table 6. For a cameraman image the direct transmission is of value 3.9735e+03, for previous approach of Yasar resulted in 582.4276 and Bilal's approach gained 135.4181 and this proposed work obtained MSE value of 64.5848. Since, every node in the network transmits the image with multiple radio terminals to implement spatial multiplexing; because of multiple

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copies of the image at the destination the performance of the network is improved.

Fig. 3 illustrates the bit error rate performance of the proposed approach. Because of spatial multiplexing, diversity order at the receiver is increased and hence the performance of the network is improved. Energy consumption of proposed approach is evaluated (shown in Fig. 4) and compared with the state-of-art approached. This is because every node transmits the image with optimal power evaluated by Eq. (8). From the simulation results it can be observe that the proposed approach improves the energy consumption by 33% (approximately).

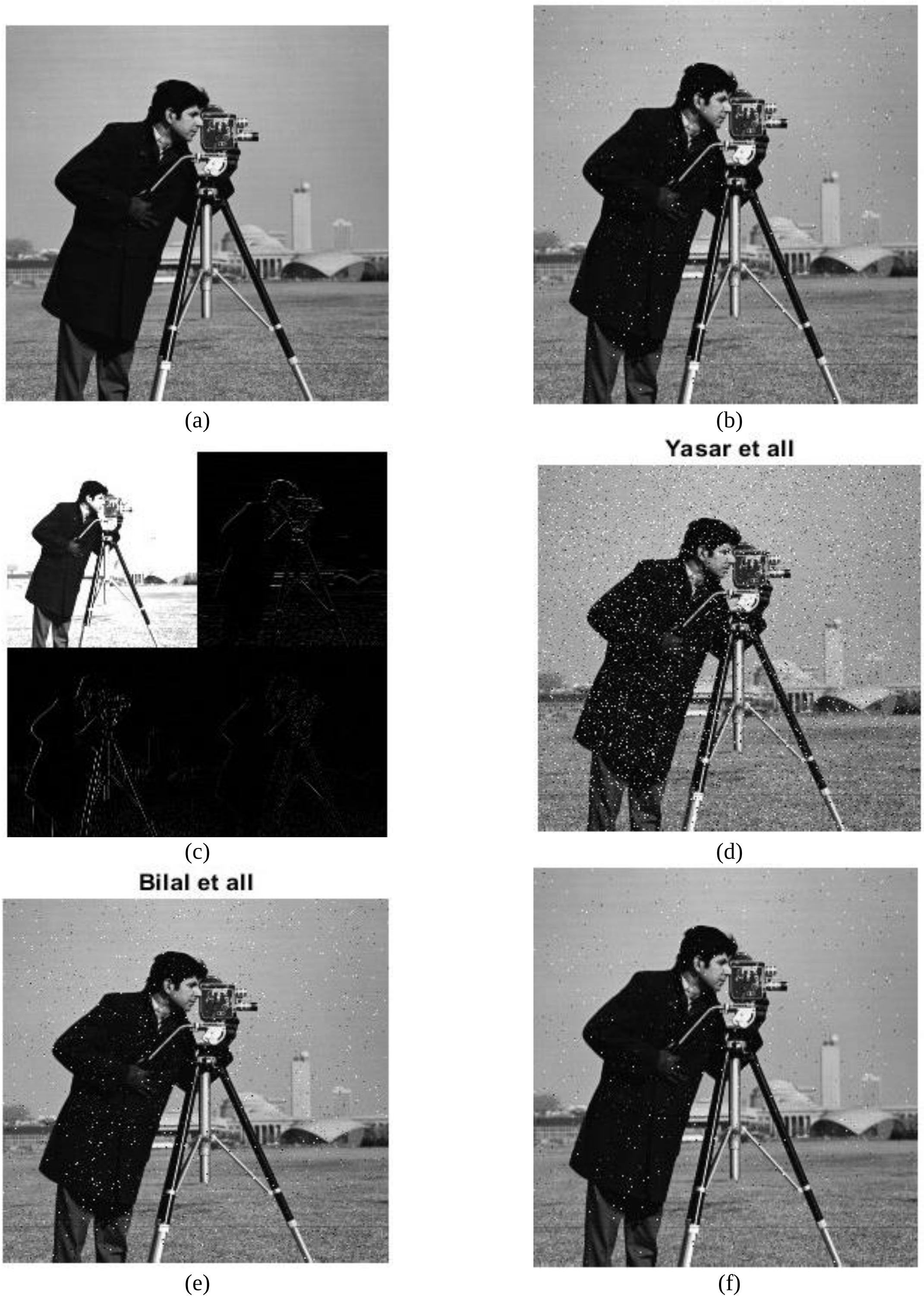

Figure. 2 Comparison between previous and proposed approaches of cameraman image: (a) Input image, (b) Sara Taher Abbas et al [15], (c) DWT, (d) Yasar et al [8], (e) Bilal et al [2], and (f) Proposed approach

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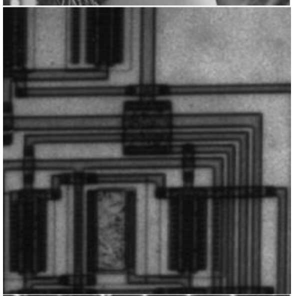
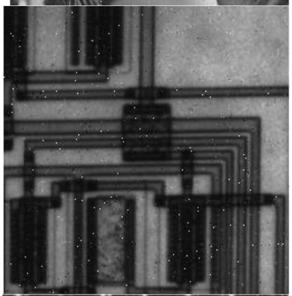
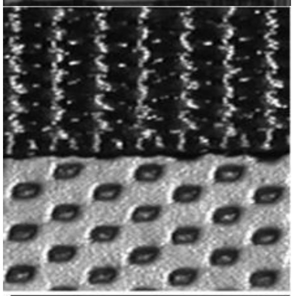
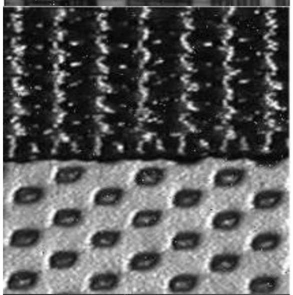
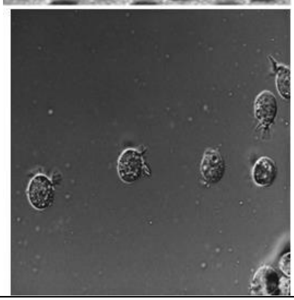
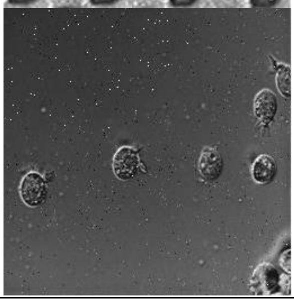
Table 3. Proposed method results on various images

Name of the image	Transmitted image	Received image
Lena		
Circuit		
Bags		
AT		

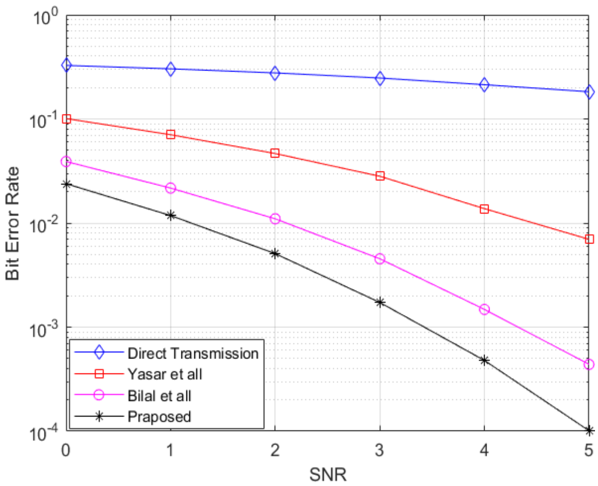


Figure. 3 BER vs SNR performance analysis

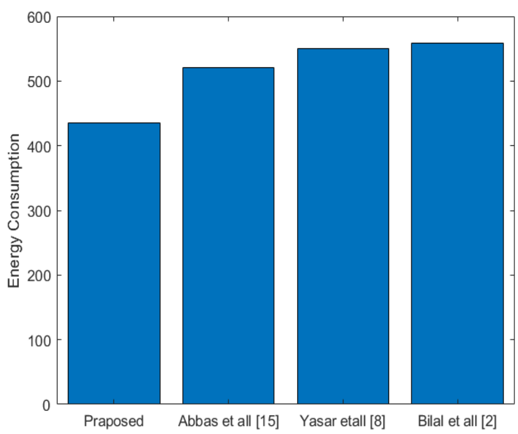


Figure. 4. Energy consumption

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6. Conclusion

Cooperative Communication is extended to large scale wireless networks to leverage the benefits of virtual MIMO. This paper presented an Energy Aware Cooperative Image Transmission approach with the aim to minimize the energy consumption for Multi-Radio Multi-Hop Wireless Sensor Networks. In this, after establishing the routing path between source and destination, source node compute the maximum power required to transmit the image to meet the target BER. The performance of the network in terms of PSNR, Structural Similarity Index (SSIM), Mean Square Error (MSE) is further improved by implementing spatial multiplexing by make use of multiple radio terminals. From the simulations, it is observed that the proposed approach saves the energy consumption up to 33% (approximately) compared to the state-of-art algorithms. An optimization technique can be incorporated to find optimal number of cooperative relays will be the future work of this research.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing-original draft preparation, writing-review editing and visualization, have been done by 1st author. The supervision and project administration have been done by 2nd, 3rd and 4th authors

References

[1] A. Nosratinia, T. E. Hunter, and A. Hedayat, "Cooperative communication in wireless networks", *IEEE Communications Magazine*, Vol. 42, No. 10, pp. 74-80, 2004.

[2] B. A. Hayani and H. Ilhan, "Efficient cooperative image transmission in one-way multi-hop sensor network", *The International Journal of Electrical Engineering & Education*, Vol. 57, No. 4, pp. 321-339, 2020.

[3] S. M. Aziz and D. M. Pham, "Energy efficient image transmission in wireless multimedia sensor networks", *IEEE Communication Letters*, Vol. 17, No. 6, pp. 841-844, 2013.

[4] W. Wang, D. Peng, H. Wang, H. Sharif, and H. H. Chen, "Energy-constrained distortion reduction optimization for wavelet-based coded image transmission in wireless sensor networks", *IEEE Transactions on Multimedia*, Vol. 10, No. 6, pp. 1169-1180, 2008.

[5] H. Wang, D. Peng, W. Wang, H. Sharif, and H. H. Chen, "Image transmissions with security enhancement based on region and path diversity in wireless sensor networks", *IEEE Transactions on Wireless Communications*, Vol. 8, No. 2, pp. 757-765, 2008.

[6] V. Lecuire, C. D. Faundez, and N. Krommenacker, "Energy efficient image transmission in sensor networks", *International Journal of Sensor Network*, Vol. 4, No. 1, pp. 37-47, 2008.

[7] E. B. Manhas, G. Brante, R. D. Souza, and M. E. Pellenz, "Energy-efficient cooperative image transmission over wireless sensor networks", In: *Proc. of IEEE Wireless Communications and Networking Conference*, pp. 2014-2019, 2012.

[8] Y. A. Rahman, M. Tariq, and T. Sato, "A novel energy efficient object detection and image transmission approach for wireless multimedia sensor networks", *IEEE Sensors Journal*, Vol. 15, No. 16, pp. 5942-5949, 2016.

[9] P. S. Boluk, S. Baydere, and A. E. Harmanci, "Robust image transmission over wireless sensor networks", *Mobile Networks and Applications*, Vol. 16, No. 2, pp. 149-170, 2011.

[10] A. Nosratinia, T. E. Hunter, and A. Hedayat, "Cooperative Communication in Wireless Networks", *IEEE Transaction of Communication Magazine*, Vol. 42, No. 10, pp. 74-80, 2004.

[11] S. Mukhopadhyay, C. Schurgers, D. Panigrahi, and S. Dey, "Model based techniques for data reliability in wireless sensor networks", *IEEE Transactions on Mobile Computing*, Vol. 8, No. 4, pp. 528-543, 2009.

[12] P. K. Devulapalli, P. S. Pokkunuri, and S. B. Maganti, "Energy Efficient Multi-hop Cooperative Transmission Protocol for Large Scale Mobile Ad hoc Networks", *Wireless Personal Communications*, Vol. 121, No. 4, pp. 3309-3328, 2021.

[13] H. Xu, K. Hua, and H. Wang, "Adaptive FEC Coding & Cooperative relayed Wireless Image Transmission", *Digital Communications and Networks*, Vol. 1, No. 3, pp. 213-221, 2015.

[14] M. Tao, H. Michael, H. Kun, D. Peng and H. Sharif, "A novel cooperative image transmission scheme in wireless sensor networks", In: *Proc. of 35th Annual IEEE Conference on Local Computer Networks*, pp. 240-243, 2010.

[15] S. T. Abbas, H. J. Mohammed, J. S. Ahmed, A. S. Rasheed, B. Alhayani, and A. Alkhayyat, "The optimization efficient energy cooperative communication image transmission over WSN", *Applied Nanoscience*, 2021.

[16] L. Zhang, R. Xu, and K. Wang, "Research on image transmission mechanism through a multimode fiber based on principal component analysis", *Optics and Lasers in Engineering*, Vol. 134, No. 1, pp. 106197, 2020.

[17] S. Wu, Q. Guan, and Z. Miao, "A New Class of LT-Based UEP Rateless Codes for Satellite Image Data Transmission", *AEU-International Journal of Electronics and Communications*, Vol. 122, No. 1, p. 153256, 2020.

[18] D. P. Kumar, P. P. Saradhi, and M. S. Babu, "Energy Efficient Transmission for Multi-Radio Multi-Hop Cooperative Wireless Networks", *Journal of Advanced Research in Dynamical and Control Systems*, Vol. 10, No. 4, pp. 117-122, 2018.

[19] D. P. Kumar, M. S. Babu, and M. S. Prasad, "Suboptimal Comparison of AF and DF Relaying For Fixed Target Error Probability", In: *Proc. of IEEE International Conference on Computer Communication and Informatics*, pp. 1-4, 2016.

[20] X. Xia, L. H. Man, and S. T. Wang, "Image filtering based on an improved spring-mass model", *Journal of Algorithms & Computational Technology*, Vol. 5, No. 1, pp. 1-13, 2011.

[21] J. Baldoni, G. Lionello, F. Zama, and L. Cristofolini, "Comparison of different filtering strategies to reduce noise in strain measurement with digital image correlation", *The Journal of Strain Analysis for Engineering Design*, Vol. 51, No. 6, pp. 416-430, 2016.

[22] V. Lecuire, C. D. Faundez, and N. Krommenacker, "Energy efficient transmission of wavelet-based images in wireless sensor networks", *EURASIP Journal of Image and Video Processing*, Vol. 1, No. 1, pp. 1-11, 2007.

[23] V. K. Goyal, "Multiple description coding: compression meets the network", *IEEE Signal Process Magazine*, Vol. 18, No. 5, pp. 74-93, 2001.

[24] V. Gupta, R. Mahle, and R. S. Shriwas, "Image denoising using wavelet transform method", In: *Proc. of IEEE Tenth International Conference on Wireless and Optical Communications Networks*, pp. 1-4, 2013.

[25] P. K. Devulapalli and P. S. Pokkunuri, "An efficient cooperative routing algorithm for large-scale wireless networks based on capacity and location", *International Journal of Communication Networks and Distributed Systems*, Vol. 26, No. 4, pp. 446-463, 2021.

[26] X. Li, X. Tao, and N. Li, "Energy-Efficient Cooperative MIMO-Based Random Walk Routing for Wireless Sensor Networks", *IEEE Communications Letters*, Vol. 20, No. 11, pp. 2280-2283, 2016.