REPUBLIC OF TURKEY

YILDIZ TECHNICAL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ENERGY-EFFICIENT SECURE COOPERATIVE BASED IMAGE TRANSMISSION IN WIRELESS SENSOR NETWORKS USING DIFFERENT SYSTEM MODELS

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DOCTOR OF PHILOSOPHY THESIS

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Communication Program

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January, 2020

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A thesis submitted by Bilal Salih Abed AL-HAYANI in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY is approved by the committee on 16.01.2020 in Department of Electronics and Communication Engineering, Communication Program.

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Bilal Salih Abed AL-HAYANI

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This study was supported by the Scientific Research Projects Coordination of Yildiz Technical University (YTU, BAP), Grant No: FBA-2017-3092.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor, Assoc. Prof. Dr. Haci ILHAN for his constant support, guidance, and motivation. It would never have been possible for me to take this work to completion without his support and encouragement. I am thankful for his supporting me during these past five years.

I have been extremely lucky to have a supervisor who cared so much about my work, and who responded to my questions and queries so promptly.

I would also like to thank the member of the committee at Assoc. Prof. Dr. Ahmet Serbes, for support me and given me new methods techniques in my research suggestionsو I am proud of him for following up on my thesis, I appreciate his contributions of time and ideas to make my work productive

I would also like to thank the member of the committee at Assoc. Prof. Dr. Ender Mete, who helped me, and he has appreciated work in this thesis along with the study period.

I would also like to thank the member of the committee at Assoc. Prof. Dr. Hamid TORPI for his appreciation of my work in this thesis for providing me an opportunity to complete my Ph.D. thesis. I appreciate his contributions to time.

I would also like to thank the member of the committee at Ass. Prof. Dr. Eşref OSMANLIOĞLU, He provided me an opportunity to complete my Ph.D. thesis. I appreciate his contributions to time, and he encourages me.

I want to give special thanks to my dissertation committee. I am a debt of gratitude for their efforts and their time to read thesis and discussion.

I must express my gratitude to my father and my mother for the continued support and encouragement to pray for me, I am thankful for the patience of my mother, and father for since six years ago to endure my absence.

I must express my gratitude to my wife and my children (Qasem, Wadq, Abdullah), they came with me from far area to another country in full period of my studies they have gained new and very nice language, They are stood beside me to finish the study. I must express my gratitude to my brothers and sisters; they supported me in different ways.

I am very thankful to all staff team in the Department of Electronics Communication; they have supported me in more information which required for the finished thesis.

Bilal Salih Abed AL-HAYANI

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LIST OF SYMBOLS

Ψ	Collection of vectors
X	Input matrix
Y	Output matrix
H	Channel matrix
N	Noise matrix
$\Psi(\omega)$	Fourier transform of $\Psi(t)$.
l(n)	Low pass filter with frequency response $L(\omega)$.
$L(\omega)$	Low-frequency data
N_{LIB}	Total number of nodes in LIB
N_{LIBS}	Number of nodes in LIBS
N_{LSP}	Number of nodes in LSP
s	Number of bits to store addressing information of a block node
I	Image captured by the transmitter node
T	Transmitter node
D	Sink or Destination node
RR	Relaying Role
MR	Monitoring Role
N	Height of the image
L	Width of the image
sgn (.)	Signum function
I_1^R	The noisy approximation coefficient at current relay node R
I_1	Approximation coefficient detected

Rn	Relay nodes
I_r	Received image
N_{err}	The entire bits error
N_{bits}	The entire bits sent
O_{SR}	Represents the original data from source S to receiver R for function
$\hat{r}$	Decoded/detected data at the relay node
α	The minimum threshold value for suppressing the noise
f_{DF}	The detection function of decoded and forward *(DF)* method
$I_1^R\ (i, j)$	The current value of noisy approximation coefficient at location (*i, j*)
E	Symbol energy
I_m	The image transmitted by the users
P_{ij}	The random measurement matrix
q_c	Frequency term
b_s	Quantity of bits every second
$\frac{U}{V}$	Signal to noise ratio
I_n	The original image reconstructed
K	Number of bits transmitted
μ_{xy}	The average among the image pixels x, y
σ_{xy}	The standard deviation of the pixels of the foundation
P_{xy}	Multiple of image intensity over each pixel

LIST OF ABBREVIATIONS

ADC	Analog to digital controller
ADF	Adaptive decode and forward
ADSL	Asymmetric digital subscriber lines
AF	Amplify and forward
AIFF	Audio interchange file format
AWGN	Additive white Gaussian noise
BAN	Body area network
BEP	Bit error probability
BER	Bit error rate
BP	Basis pursuits
BPSK	Binary phase shift keying
BS	Base station
BV	Bounded variation
C3I	Command, control, communication and intelligence systems
CD	Cooperative diversity
CF	Compress and forward
CS	Compressive sensing
CSI	Channel state information
DAB	Digital audio broadcasting
DAC	Digital to analog converter
DCT	Discrete cosine transform
DF	Decode and forward
DFT	Discrete Fourier transforms
DIP	Digital image processing

DST	Discrete sine transform
EGC	Equal gain combining
EP	Extended part
ERP	Enterprise resource planning
FEC	Forward error correction
FFT	Fast Fourier transform
GPS	Global positioning system
HDSL	High bit rate digital subscriber lines
HDT	High definition television
IC	Interference cancellation
IFFT	Inverse fast Fourier transform
L2R	Left to right
LIB	List of insignificant blocks
LIBS	List of insignificant block sets
LIP	List of insignificant pixels
LIS	List of insignificant sets
LSP	List of significant pixels
MGF	Moment generating function
MIMO	Multiple input multiple output
MISO	Multiple input single output
ML	Maximum likelihood
MMSE	Minimum mean square error
MR	Monitoring role
MRC	Maximal ratio combining
MSE	Mean square error
OMP	Orthogonal matching pursuit

OMPR	Orthogonal matching pursuit with replacement
OSI	Open systems interconnection
PDA	Personal digital assistant
PP	Padded party
PP	Pixel-position
PSNR	Peak signal to noise ratio
PV	Pixel-value
QAM	Quadrature amplitude modulation
QoS	Quality of service
QPSK	Quadrature phase shift keying
R2L	Right to left
RIP	Restricted isometry property
RMSE	Root mean squared error
ROMP	Regularized OMP
RR	Relaying role
SDF	Selective decode-and-forward
SEP	Symbol error probability
SIC	Self-interference cancellation
SIMO	Single input multiple output
SISO	Single input single output
SOT	Spatial orientation trees
SSIM	Structural similarity index measure
TVSD	Total variation sequence detection
VDSL	Very high speed digital subscriber lines
VSN	Visual sensor networks
WAV	Audio file format

WLAN	Wireless local area network
WMSN	Wireless multimedia sensor network
WSN	Wireless sensor network
ZF	Zero forcing

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ABSTRACT

Energy-Efficient Secure Cooperative Based Image Transmission in Wireless Sensor Networks Using Different System Models

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Department of Electronics and Communication Engineering

Doctor of Philosophy Thesis

Advisor: Assoc. Prof. Dr. Hacı İLHAN

Nowadays, wireless sensor networks (WSNs) are widely used for the different multimedia applications in which the data in multimedia form (e.g., images and videos) are captured by visual sensors and transmitted to base station or destination nodes, and such networks commonly called as wireless multimedia sensor networks (WMSN) to transmit high-quality image over sensor nodes needing high throughput, less bit error rate (BER) and more transmission rate with less consumption of energy parameters. For WMSNs, energy efficiency and security are two major concerns as the high dimensional and sensitive digital images consume more processing capabilities of sensor nodes. Thus, it requires the development of energy-aware multimedia processing algorithms to transmit digital images in WMSN without compromising security and quality. The cooperative image transmission methodology over sensor networks is proven to be an effective solution in the recent past.

In the first contribution of the thesis, we propose energy efficiency and quality-aware multi-hop one-way cooperative image transmission framework based on

image pre-processing technique, wavelet-based two-dimensional discrete wavelet transform (2D-DWT) methodology, and decode and forward (DF) algorithm at relay nodes.

In the second contribution, along with the image quality improvement and compressive sensing (CS) technique, the security of CS data has been achieved. The one-way DF based cooperative secure digital image transmission model over WSNs uses advanced terminologies for image compression called optimization JPEG2000 compression, and modified Elliptic curve cryptography (ECC) encryption is proposed.

In the final contribution of this thesis, one-way image transmission in the MIMO communication model is proposed for secure digital image transmission over the WSNs.

The simulation results of each contribution of this thesis are presented in comparison with the new state-of-art methods. The obtained results prove that the proposed digital image transmission models provide an improvement in energy efficiency, security and service quality (QoS).

ÖZET

Farklı Sistem Modelleri Kullanan Kablosuz Sensör Ağları Üzerinden Güvenli Enerji Verimli İşbirlikli Görüntü Aktarımı

Bilal Salih Abed AL-HAYANI

Elektronik ve Haberleşme Mühendisliği Bölümü

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Günümüzde, kablosuz sensör ağları (WSN), multimedya formundaki verilerin (örneğin görüntüler ve videolar) görsel sensörler tarafından yakalandığı ve genellikle kablosuz multimedya sensör ağları (WMSN) olarak adlandırılan ağlar gibi baz istasyonu düğümlerinin iletildiği farklı multimedya uygulamaları için yaygın olarak kullanılmaktadır. WMSN'de yüksek kaliteli görüntüyü sensör düğümleri üzerinden iletmek için daha az bit hata oranı (BER) ve daha az enerji tüketimi ile daha fazla iletim hızı gerekir. Bu nedenle, güvenlik ve kaliteden ödün vermeden WMSN'deki sayısal görüntüleri iletmek için enerjiye duyarlı çoklu ortam işleme algoritmalarının geliştirilmesini gerektirir. Sensör ağları üzerinden işbirlikli görüntü aktarım metodolojisinin yakın geçmişte etkili bir çözüm olduğu kanıtlanmıştır.

Tezin ilk katkısında, görüntü ön işleme tekniğine, dalgacık tabanlı iki boyutlu ayrık dalgacık dönüşümü (2D-DWT) metodolojisine dayanan enerji verimliliği ve

kaliteye duyarlı çöz ve aktar (DF) kullanan çok atlamalı tek yönlü işbirlikli sistemlerde görüntü aktarımının WSN ağlardaki performansı incelenmiştir.

Tezin ikinci katkısı olarak, görüntü kalitesi iyileştirme ve CS (Compressive sensing) tekniği ile birlikte CS verilerinin güvenliği sağlanmıştır. Gelişmiş JPEG2000 sıkıştırma ve değiştirilmiş eliptik eğri şifreleme (ECC) olarak adlandırılan gelişmiş görüntü sıkıştırma terminolojileri kullanan WSN'ler üzerinde tek yönlü DF tabanlı işbirliğine dayalı sayısal görüntü aktarım modeli önerilmektedir.

Bu tezin son katkısında, WSN'ler üzerinden güvenli sayısal görüntü aktarımı için çok girişli çok çıkışlı (MIMO) iletişim modelinde tek yönlü görüntü aktarımı önerilmektedir.

Bu tezin her bir katkısının simülasyon sonuçları, yeni teknoloji yöntemleriyle karşılaştırılmıştır. Elde edilen sonuçlar, önerilen sayısal görüntü iletim modellerinin enerji verimliliği, güvenlik ve hizmet kalitesinde (QoS) iyileşme sağladığını kanıtlamaktadır.

1
Introduction

1.1 Literature Review

In this thesis work, several domains such as wireless communications, image processing (compression and cryptography), modulation techniques, cooperative transmissions, and WSNs are examined. In this part, we present the study of such techniques. In the literature survey, the survey starts with a cooperative image transmission framework and designs followed by a study of different image compression algorithms and coding techniques. The image cryptography algorithm is described after that. Finally, the review of state-of-the-art methods on cooperative image transmission, new compression methods, and security algorithms are shown. In Section 1.1.1, the study of wireless communication, types of wireless communications, the functionality of MIMO communications along with their advantages, disadvantages, and applications are explained. Cooperative communication is described and we present the study of different types of relaying techniques in cooperative communications. The survey of various image compression and coding techniques used in the image transmission domain is presented and gives a review of works related to cooperative communication. In Section 1.1.2, this investigation aims to design a secure and energy-productive helpful image information transmission strategy over wireless channels in WSNs with different cooperative communication system models. The focus is on image quality improvement in the transmission from source to the destination node via a relay node. In Section 1.1.3, the general study architecture of the proposed cooperative digital image transmission framework is presented. The goal of this research work is to present secure, energy-efficient, and robust cooperative image transmission over wireless sensor systems utilizing novel techniques and techniques with different system models of communications.

1.1.1 Wireless Communications

Wireless communication is one of the predominant modes used to share information from source to destination. It has been growing rapidly in industrial, medical, education, and other developing sectors. Wireless technologies are employed at radio frequencies for information to be conveyed to the consumers quickly and without any loss. The messages are transmitted through channels without any wires so that the work can be done anywhere and at any time. The significant applications of wireless technologies are in mobile telephones, radio receivers, telecasts, and wireless networking. Applications in Figure 1.1 are showing an example design of wireless sensor networks (WSN) with all components involved [1], such as video conferencing, which require a high data rate to transmit the information in a short time. Though the increase in mobility of wireless communication technology is tremendous, the cost of the installation and maintenance of the wireless components needs to be minimized. Wireless signals are propagated into the air with noise added into the signal. As a result, the signal strength is decreased, increasing the loss of data. The primary goal of the wireless communication system is to limit the error and maximize the data rate or system capacity, especially in multimedia communications.

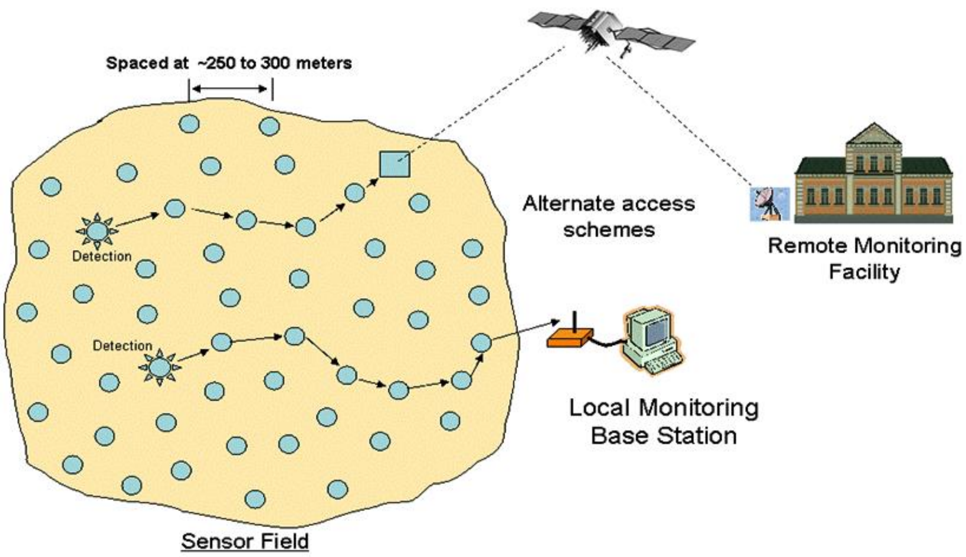

Figure 1.1 Example of WSNs design and application

1.1.2 Wireless Multimedia Sensor Network

Sensor nodes speak with one another through a radio connection in a multi-hop manner. They broadcast the measured event to the nodes within their transmission range, and finally, the event reaches the network operator at the monitoring site. Sensor nodes broadcast the measured event only after in-network processing, which makes it unsuitable for applications that deal with a huge volume of data. Wireless multimedia sensor network (WMSN) has belatedly got the idea of the examination network because of the progression of complementary metal-oxide-semiconductor (CMOS) cameras [2]. WMSN gives a vast extent of potential applications in both standard occupant and military areas which require visual data, for example, reconnaissance, natural and mechanical checking, traffic blockage control, medicinal services, and green city applications. While there are many applications for WMSN, this thesis targets those applications in which the digital images are transmitted over WSNs.

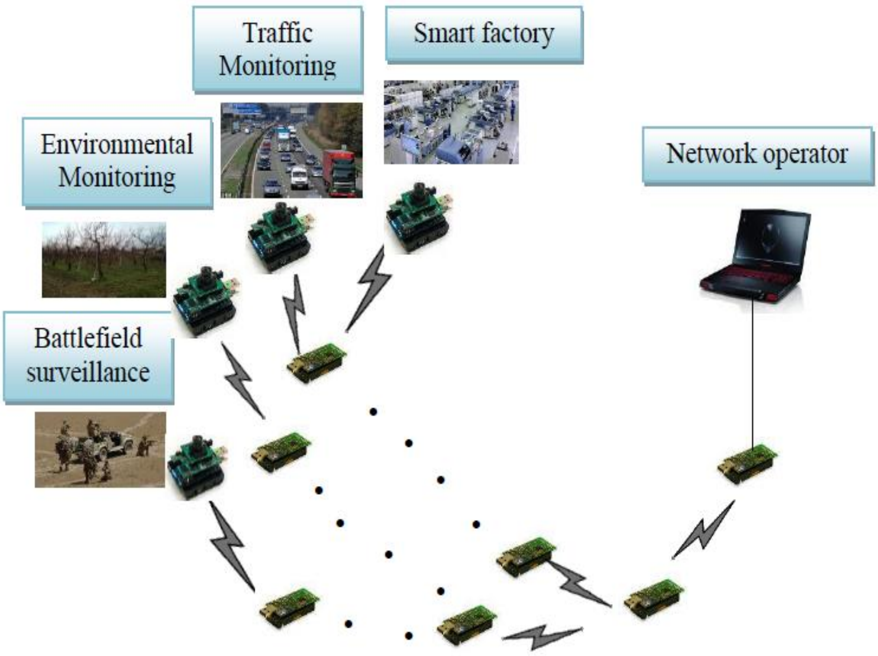

Figure 1.2 Applications of WMSN

Figure 1.2 gives an overview of WMSN in which camera nodes are put in the observation zone to be checked. The captured video is transmitted to the monitoring site in a multihop manner using regular nodes. The availability of

CMOS cameras has encouraged the advancement of WMSNs, which comprise remotely interconnected multimedia capable sensor nodes [3]. These multimedia sensor nodes extensively recover multimedia substances, for example, video and sound streams, still pictures, and scalar sensor data from nature. The mixed-media information collected from the environment is processed and transmitted [4].

Handling video data imposes a few challenges on the network, such as high bandwidth demand, ongoing conveyance, mediocre start-to-finish postponement, and edge misfortune rate. Additionally, there are numerous asset limitations in WMSNs, including vitality, bandwidth, information rate, memory, and preparing capacity. Security in sensor networks is a highly challenging job as it is used for sensitive applications such as surveillance and building monitoring in airports and hospitals. These challenges can be met with the help of an efficient compression algorithm to handle high data rates and efficient security mechanisms for dealing with the security attack [5], [6].

- **QoS requirements:** Audio/video storage, system snapshots, streaming media, play-back capacities have different capacities as for jitter, postponement, and misfortune lenience that require a new look at offering essential QoS services.
- **Bandwidth:** Strictly limited the obtainable bandwidth as WMSNs need transmission data transfer capacity that is much more than the capacity of reachable sensors.
- **Power:** Power utilization is the main anxiety than in conventional wireless sensor networks as multimedia functions create large volumes of information that need higher transmission rates and widespread dispensation than in traditional wireless sensor networks.
- **User monitoring facility:** The protocol architecture is of fundamental significance for the saleable improvement of sensor networks to give services that permit doubting the network to recover helpful information.
- **Leveraging of in-network support:** Dispensed databases of multimedia information, counting dispensed memory and guiding of data inside the

network itself, in-network routing systems require to be enlarged to extract appropriate information from current data resourcefully.

1.1.3 MIMO Communications

Wireless communication technology has been developed rapidly due to the increase in the mobility of users. Different information yield system is one of the popular techniques in which numerous radio wires are utilized both, in the transmitter and the receiver, to update the data rate. In the transmitter, the signal is transmitted via various antennas at the same frequency [7], [8]. Single and multiuser multiple input multiple output technology has been implemented and developed in IEEE802.11n products. There are special types of MIMO systems: Single input single-output (SISO), Single-input multiple-output (SIMO), Multiple-input single-output (MISO), and Multiple-input multiple-output (MIMO). Multiple antennas are used to achieve array gain that increases the bandwidth efficiency, link reliability, the capacity of the channel, and reduces the effect of the multipath fading [9]. The fundamental point of the MIMO framework is to limit the probability of fading and maximize the transmission speed [10].

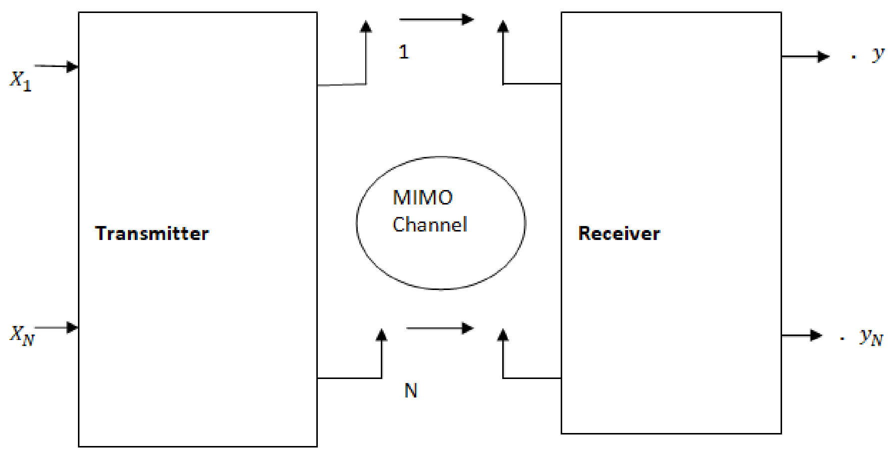

Figure 1.3 MIMO channel model

In Figure 1.3, the MIMO channel model with its multiple transmit antennas transmit multiple information at the same frequency, the information is sent to the matrix channel that has N number of ways between the transmitter and the receiver [11]. The noisy signal captured by the receiving antenna is decoded and then converted into the original information. MIMO system is defined as

$$Y = HX + N . \tag{1.1}$$

where X is the input matrix, Y is the output matrix, H is the channel matrix, and N is the noise matrix.

MIMO technology has been implemented and developed in IEEE 802.11n products. Mostly, it uses 2x2 and 3x3 MIMO systems. IEEE is a professional association that provides electronics and electrical technologies, and IEEE 802.11n is the standard that can maintain wireless networking with the help of IEEE, using the channel-based system based on the network operation [12]. It is the most complicated networking standard that is to be properly configured and optimized. IEEE 802.11n provides improved performance operating at 2.4 GHz and 5 GHz frequency band using two important technologies, namely, 40 MHz wide channels and 20 MHz channels. MIMO has multiple transmit-and-get receiving wires to send and get the information, improving the performance significantly [13]. IEEE 802.11n provides the maximum data rate of 150 Mbps. The 1x1 wireless devices use the single 802.11n standard transmit and receive antennas. The 2x2 MIMO product provides double the amount of data rate of 300 Mbps and is used in several applications, including mobile phones, because of the small size of the device, though installing multiple antennas in the device is difficult. If it is 1x1 MIMO configuration, the maximum data rate 72 Mbps for 20 MHz channel width and 150 Mbps for 40 MHz channel width. Similarly, the maximum data rate is 144 Mbps for 20 MHz channel width and 300 Mbps for 40 MHz channel width in 2x2 MIMO configurations [14], [15].

A. Advantages of MIMO Systems

- **Coverage range:** Because of the impact of the coherent combining wireless framework, a gain of an array of average radio signals can be found as per enhanced signal-to-noise ratio at the destination which results in enhancement of ratio of resistance to noise. The impact of this factor will increase the covering radius of the framework.

- **High effect of diversity:** The power of the signal at the destination randomly varies in the remote framework. The powerful approach is diversity. Due to higher autonomous copies not less than single, there are no expands in fading, thus augmenting the reliability and high quality of the signal.
- **Spatial multiplexing gain:** MIMO framework gives a direct rise in capacity without the necessity of extra spectrum utilization or expansion in power transfer. With acceptable conditions of the channel, the elements at the destination can isolate information series. Moreover, every information stream channel experiences, in any event, the same quality as contrasted with a SISO framework to successfully enhance capacity with increased component equivalents of the quantity of series. By and large, it is conceivable to securely get the channel of MIMO that is equivalent to a little number of series of an element at input and destination.

1.1.4 Cooperative Communications

In the present era, people depend on wireless technology; the demand for high data rates in remote correspondence becomes even more. The number of clients who need this new technology has seen an upward increase. Wireless innovation has seen tremendous advances in the past years [15]. However, some physical parameters of wireless technology need to be improved to offer optimum benefit to the clients. In most of the cases, battery life, restricted recurrence band, and serious fading channels are causes that need to be addressed [16].

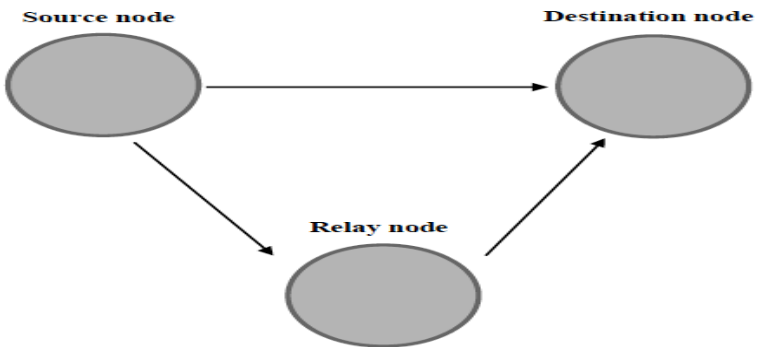

Figure 1.4 General structure of cooperative communication

Cooperative communication can address the issue of longer battery life. It is a framework where wireless mobiles can transmit their signals simultaneously, thus achieving many significant improvements in communication over multipath fading channels. These improvements include high data rates for data communication, enhanced clarity and coherence for voice communications, reduced transmission power, and expanded battery life. The essential guideline of helpful correspondence is using other correspondence devices to operate hand-off transmission [16], [17]. Figure 1.4 shows data broadcasting from the source node to both the nodes, i.e., destination node and the relay node. The relay node then forwards the transmission to the endpoint (destination) node. The source center point sees the exchange center as a virtual antenna, enabling MIMO systems to be used without including a physical receiving wire [18].

The size and power constraints of a mobile unit make it impossible to mount multiple transmit antennas, which limit the capacity of transmission from mobile units to base stations in existing mobile communication scenarios. This has driven the rapidly growing research on transmit antenna diversity to user cooperation. To achieve transmit diversity in the uplink, other in-cell clients' radio wires can be shared agreeably [19]. This method of grabbing transmit of a decent variety is called cooperative diversity (CD). Cooperative diversity methods relieve the impacts of transient fading just as the effects of long term fading, i.e., shadowing, by choosing the partner who does not experience shadowing [20]. In a cooperative diversity scheme, mobile users share the time or frequency and different assets to transfer the user data to the recipient (called base station). For instance, as indicated in Figure 1.5, two mobile sensors (called sender and receiver) collaborate and transmit the information to the recipient. In the first stage, the sender transmits its data to both the destination and the receiver [21].

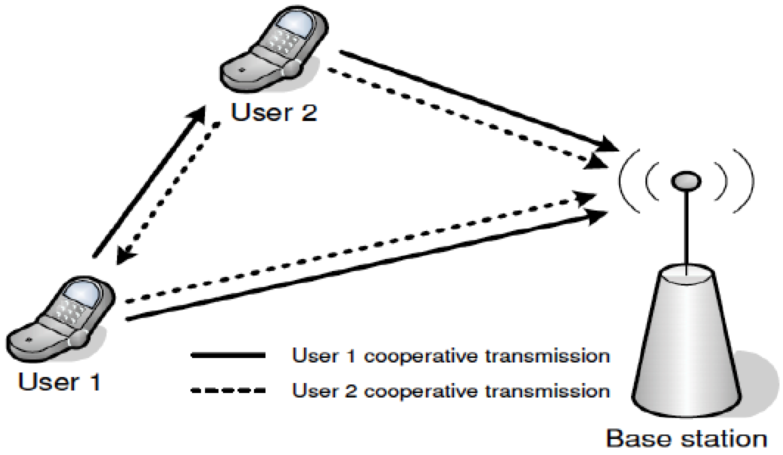

Figure 1.5 Cooperative transmissions between two users

In such communication, higher frequency components exhibit bad propagation characteristics, while lower frequencies suffer from the problem of low data rates. Due to this reason, the available frequency spectrum which can be used for efficient transmission is limited and hence is a limited resource. For efficient transmission of data, there are two main performance measures, Bit Error Probability (BEP) and Spectral efficiency. In communication systems, there is a trade-off between these two. Some technique is spectrally efficient such as SISO system but exhibits higher bit error probabilities. MIMO technique provides better BEPs but is mainly spectrally inefficient. The main objective of researchers is to find a technique that is spectrally efficient and provides considerable BEPs as well. A relay network is a wide range of network topology frequently utilized as a part of cooperative wireless networks, where the source and destination are interconnected using nodes. In its simplest form, a cooperative network is composed of a source node, a destination node and a relaying node, which supports communication between source and destination. If the direct communication between the source-destination pair is faulty, then the overheard information can be relayed to the destination by the relaying node.

1.1.5 Relaying techniques

In cooperative networks, two main relaying protocols will be given in the next subsection.

A. Amplify and forward

Fundamental cooperative flagging is the amplify-and-forward (AF) strategy. As the name suggests, the client at that point can amplify and re-transmit the got information in the noisy structure. The destination node combines the data sent by the customer along with some extra data and picks an end choice on the transmitted information (Figure 1.6). Even though noise is amplified by cooperation, the destination node gets two self-rulingly faded variants of the signal and can settle on better choices on the location of data [22].

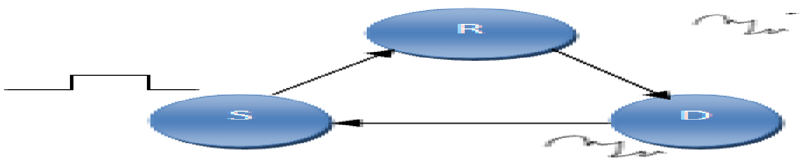

Figure 1.6 Amplify and forward relaying technique

B. Decode and Forward

This arrangement is nearest to the thought of a customary relay. In this strategy, a user needs to recognize the receiver's bits and, after that, re-transmits the perceived bits (Figure 1.7). The authorities may be assigned for the most part by the base station or through some other framework. Consider two users collaborating, yet practically speaking, the principle vital issue is that each client has a recipient that gives an extra (diversity) information way. The most straight forward strategy to imagine this is by methods for sets, yet it is conceivable to accomplish a comparative impact through other alliance topologies that void the severe constraint of blending [23].

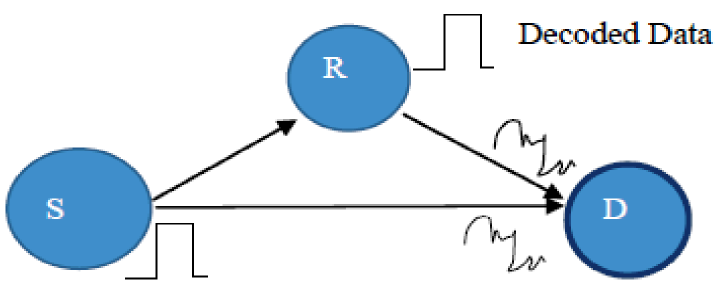

Figure 1.7 Decode and forward delaying technique

1.1.6 Image compression for Wireless sensor networks

Wireless sensor networks (WSNs) with imaging abilities are highly constrained as far as memory, handling capacity, and battery power go as they have to transmit images on remote systems that suffer by high probability and burstiness of noise. It is also important that the computational cost of compression is less than related to the cost of transmission to enhance energy efficiency and elongate the life of the network. Therefore, a fast and efficient image compression algorithm with low memory requirement and bit rate scalability (embeddedness) is apt for execution on these frameworks [24].

The characteristics of the various image compression algorithms are presented in [25]. Although JPEG 2000 provides the highest coding efficiency, JPEG2000 compression is a very time and energy-consuming method and is therefore not suitable for implementation in the recourse-constrained environment. In [26], it is shown that compression and transmission, using JPEG is more energy inefficient than transmitting the image without compression with a high-quality level. In [27], it has been concluded that SPIHT gives the highest coding efficiency while achieving the best compromise between the quality of reconstructed image and energy consumption. Also, SPIHT is preferred over EBCOT coding for hardware implementation. SPECK coder because of its simplicity, coding efficiency and low memory are a more suitable candidate among the wavelet-based embedded coders for implementation in WMSN and VSN, Low memory version of SPECK image-coding algorithm is desired for resource-constrained handheld multimedia devices, and VSN/ WMSN.

1.1.7 Transform based image compression

Image coding strategies utilize a numerical change to delineate image pixel respect to a lot of de-associated coefficients; in this way, expelling between pixel repetitions. These coefficients are then quantized (psycho-visual reiteration) and encoded (coding capacity). The critical factor for the achievement of progression-based coding plans is their uncommon noteworthiness compaction property, for example, a huge division of absolute vitality of image is pressed in a couple of coefficients. There are different sorts of image transforms like a discrete Fourier transform (DFT), discrete sine transform (DST), discrete cosine transform (DCT), Karhunen-Loeve transforms (KLT) and discrete wavelet transform (DWT) [28]. Even though KLT transform is best as far as vitality compaction (transform coding gain), one drawback of KLT transform is that it is data-dependent and overhead of sending the transform may reduce the transform coding gain. Another popular transform is DCT, which offers transform coding gain closer to KLT and higher than DFT. Also, the computational complexity of DCT is less than DFT. Due to these reasons, the DCT has become the most widely used transform coding technique [29], [30]. The 1D discrete cosine transform (DCT) coefficient given by Equation 1.2. And inverse DCT is given by Equation 1.3 respectively.

$$y(k)=\theta(k)\sum_{n=0}^{N-1} x(n)\ \cos\left[\frac{(2n+1)k\pi}{2N}\right],\quad 0 \le k < N-1 \tag{1.2}$$

$$x(n)=\sum_{n=0}^{N-1} \theta(k)\ y(k) \cos\left[\frac{(2n+1)k\pi}{2N}\right],\quad 0 \le n < N-1 \tag{1.3}$$

Where $\theta(0) = \sqrt{\frac{1}{N}}$, $\theta(k)=\sqrt{\frac{2}{N}}$ $for\, 1 \le k < N-1.$

1.1.8 Image compression using Wavelet Transform

The Discrete Wavelet Transform (DWT) is the transform adopted by the recent image compression standard JPEG2000 [31] and is the most noticeable transform used in image coding nowadays. It significantly outperforms algorithms based on other transforms, such as the DCT. The achievement of the DWT lies in the ease of computation and its decomposition of an image into spatial sub-blocks that empower the structure of capable quantization and allows the misuse of the human visual framework characteristics. The advantage of wavelet transform is that they are equipped for speaking to an image with various degrees of goals [32], [33], but then keep up the significant compaction properties of the DCT in this manner the subdivision of the information picture into progressively little sub-pictures is never at the center as occurs in DCT-based coding. An important property of wavelet transform is the conservation of energy (sum blocks of pixel values). Wavelet transform results in the energy of the image divided between approximation and details images, but the total energy remains constant. In lossy compression, loss of energy occurs because of quantization [34], [35].

Another property of wavelet transform is energy compression. The compression of energy describes how much energy has been compressed into the approximation image during wavelet analysis. Compaction will occur wherever the magnitudes of the detail coefficients are significantly smaller than that of the approximation coefficients. Compression is an important property of wavelet transform is the conservation of energy (sum of the square of pixel values). Wavelet transform results in the energy of the image divided between approximation and details images, but the total energy remains constant. In lossy compression, loss of energy occurs because of quantization, [36].

Another property of wavelet transform is energy compaction. The compaction of energy describes how much energy has been compacted into the approximation image during wavelet analysis. Compaction will occur wherever the magnitudes of the detail coefficients are significantly smaller than that of the approximation coefficients. Compaction is important when compressing signals because the more energy compaction into the approximation image, the higher compression efficiency may be obtained.

Wavelet transform decomposes the signal into various sub-bands, each of which has its own spatial orientation feature that can be efficiently used for image coding. Another property of wavelet transform is that quantization error $e_{m,n}$ introduced to coefficient $x_{m,n}$ will appear as a scaled version of the wavelet function superimposed on the reconstructed signal. In image coding, this implies that a quantization error from the coefficient will not remain confined to the location but will spread through the reconstructed image with the shape of the corresponding wavelet. Wavelet transform offers various benefits and wavelet coding has been at the core of the many states of art image coders [37], [38].

The DWT is an implementation of the wavelet transform using a discrete set of the wavelet scales and translations obeying some defined rules. This transform decomposes the signal into a mutually orthogonal set of wavelets, which is the main difference from the continuous wavelet transform (CWT) or its implementation for the discrete-time series sometimes called discrete-time continuous wavelet transform (DT-CWT). The wavelet can be constructed from a scaling function DWT is implemented using filter banks. A filter bank consists of filters, which separates the signal into frequency bands of an equal band [39]. Consider the filter bank shown in Figure 1.8, where a discrete signal x(n) is applied to a system consisting of a pair of filter banks. Given this signal sequence x(n) and its corresponding z-transform X(z), a lower resolution signal can be obtained by low pass filtering with half band low pass filter having impulse response l(n) with z – transform L(z). Then half band signal can be made full band signal by downsampling by a factor of two. The "added details" of the signal can be computed in a similar manner as high pass filter version of x(n) using a filter with impulse response h(n) and z transform H(z), followed by downsampling by a factor of two as depicted in Figure 1.8. At the receiving end, the signal x'(n) is reconstructed using the filter l(n) and h(n) with z-transform L'(z) and H'(z), respectively.

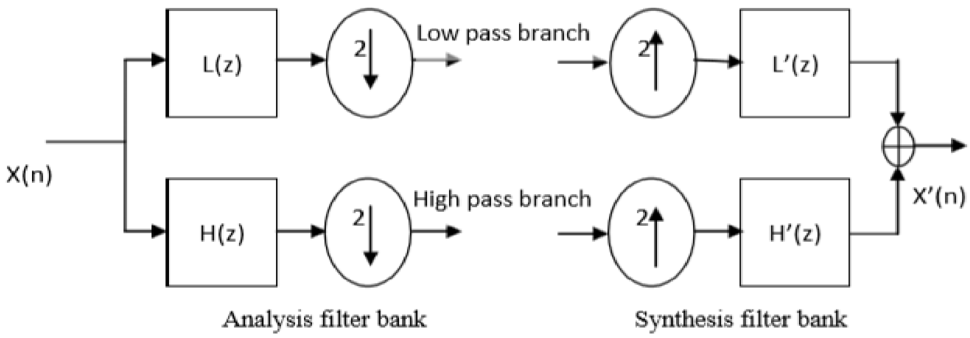

Figure 1.8 Basic two-channel filter bank structure

For the error-free channel, original signal can be reconstructed if and only if, $L'(z) = 2L(z)$, $H'(z) = -2H(z)$ and $H(z) = L(-z)$, under these conditions z transform of the output x'(n) $X'(z) = [L^2(z) - H^2(z)]X(z)$.

Perfect reconstruction is guaranteed if and only if, $[L^2(z) - H^2(z)] = 1$ If l(n) is a linear phase finite impulse response (FIR) filter with even number of coefficients then above condition holds if $[L^2(\omega) - H^2(\omega - \pi)] = 1$. A filter that meets the above constraints are said to possess perfect reconstruction properties and are often called Quadrature Mirror Filters (QMF's) or conjugate Mirror Filters (CMF„s) and is used for multi-resolution sub-band decomposition using wavelets [40]. The DWT decomposes the images in two ways such as 1D-DWT and 2D-DWT.

A. 1D-DWT

The one-dimensional discrete Wavelet Transform (1D-DWT), source images of size N, say, are split up into two coefficients: approximation coefficients CA_1 and detail coefficients CD_1. This is done by applying a *Lo D* (low pass filter) for approximation and *Hi D* (high pass filter) for detail on *s* before the dyadic decimation is employed. ID-DWT coefficients given by equations

$$W_{\emptyset}(j_{0,}, k) = \sqrt{\frac{1}{M}} \sum_x f(x)\, \emptyset_{j_0,k}(x) \tag{1.4}$$

$$W_{\Psi}(j_{,}, k) = \sqrt{\frac{1}{M}} \sum_x f(x)\, \Psi_{j,k}(x) \qquad \text{For } j \geq j_0 . \tag{1.5}$$

Here f(x), $\emptyset_{j_0,k}(x)$, and $\emptyset_{j,k}(x)$ are functions of the discrete variable x= 0,1,2,.M-1.

The $\emptyset$ *one − dimensional scalling function and* Ψ corresponding wavelet. The coefficients defined approximation and detail coefficients in Equations (1.4) and (1.5), respectively.

The single-level DWT system decomposition is shown in Figure 1.9. The length of each coefficient is computed as:

$$\left[\frac{(N-1)}{2}\right] + L \tag{1.6}$$

Where N is the height of the image, and L is the width of the image. The single-level compression system 1D-DWT is susceptible to data loss and this makes 2D-DWT a far more superior technique giving a better result.

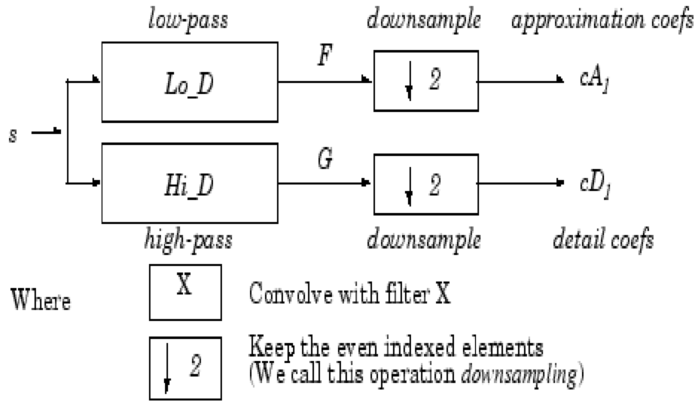

Figure 1.9 1D-DWT decomposition

B. 2D-DWT

The technique two-dimensional discrete Wavelet Transform (2D-DWT) applies the decomposition procedure to approximation coefficients at level *j.* The four elements involved are the approximation at level j+1 and the three orientations: horizontal, vertical, and diagonal. Inverse 2D-DWT is employed for decompression at the receiver end of the operation decomposition. The pre-processed image is compressed using 2D-DWT resulting in four blocks of the input image. The 2D-DWT coefficients given as equations

$$W_{\emptyset}(\mathrm{J}_0, m, n) = \sqrt{\frac{1}{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(\mathrm{x}, \mathrm{y}) \emptyset_{\mathrm{J}_0, m, n}(\mathrm{x}, y) \tag{1.7}$$

$$W_{\Psi}(\mathrm{J}, m, n) = \sqrt{\frac{1}{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(\mathrm{x}, \mathrm{y}) \Psi_{\mathrm{J}, m, n}(\mathrm{x}, y) \tag{1.8}$$

where m the one-dimensional case and $\mathrm{J}_{0,}$ is an arbitrary starting scale. And $W_{\emptyset}(\mathrm{J}_{0,}, m, n)$ coefficient.define an approximation of $f(\mathrm{x}, \mathrm{y})$ at scale J_0.The $W_{\Psi}(\mathrm{J}, m, n)$ *coefficents add* horizontal, vertical and diagonal details.

It involves constructing the original image from the four input coefficients received in the process. 2D-DWT representation of an image in Figure 1.10 demonstrates one time of the subband decomposition of an image. Wavelet-based decomposition of an image can be interpreted as an image filtering process. For an image A of size2^nx2^n, and can be performed as follows: The wavelet filter l(n) is a low pass filter with frequency response L(ω). 2D-DWTsystem decomposition is shown in Figure 1.10

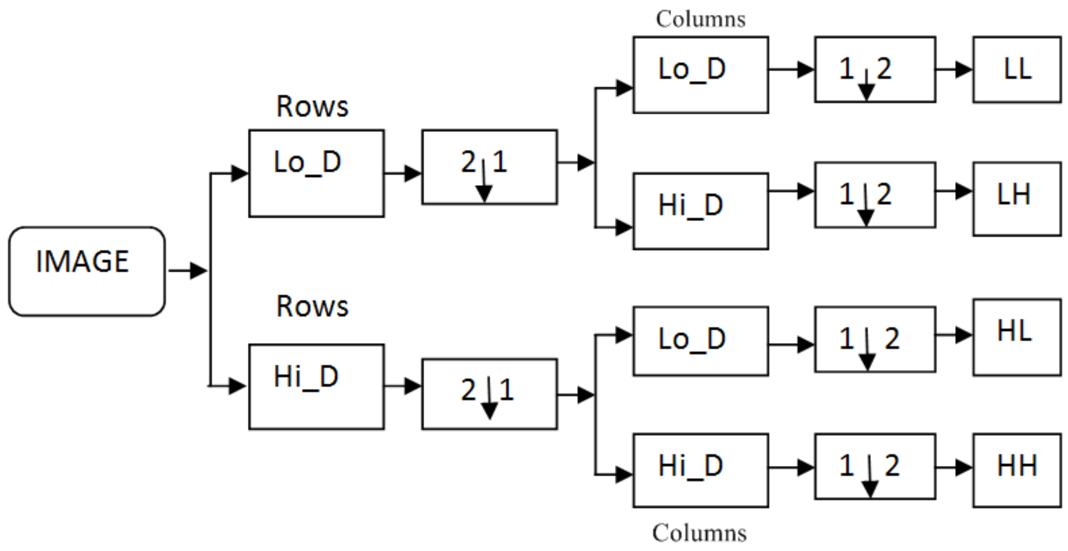

Figure 1.10 2D-DWT

Filtering the image A with L(ω) gives low-frequency information or the background of the image, whereas H(ω) gives the high-frequency information corresponding to edges in the image. Subsequent downsampling by a factor of two gives two sub-bands, L_{1r}A and H_{1r}A of image A (subscript r denotes that filtering is applied on rows of the image). Since the downsampling factor of two is applied in a vertical direction of each sub-band, the size of this two down-sampled sub-band is 2^{n}x2^{n-1}. The filter L(ω) and H(ω) are then applied on columns of the images L_{1r}A and H_{1r}A followed by downsampling by two resulting in four sub-bands each of size 2n-1 x 2n-1; $L_{1c}L_{1r}$A (low-resolution sub-band), $L_{1r}\,H_{1r}$A (horizontal orientation sub band), $L_{1c}H_{1r}$A (vertical orientation sub-band), and $H_{1r}H_{1c}$A (diagonal orientation sub band).

The low-resolution sub-band contains the smooth information (low frequency) and background intensity of the image, while other sub-bands contain the detail (high frequency) information of the image [41], [42]. The figure shows an image decomposition structure. Reversing the same process can perform reconstruction of the original image. The wavelet output of one level sub-band decomposition of image “Barbara” is shown in Figure 1.12.

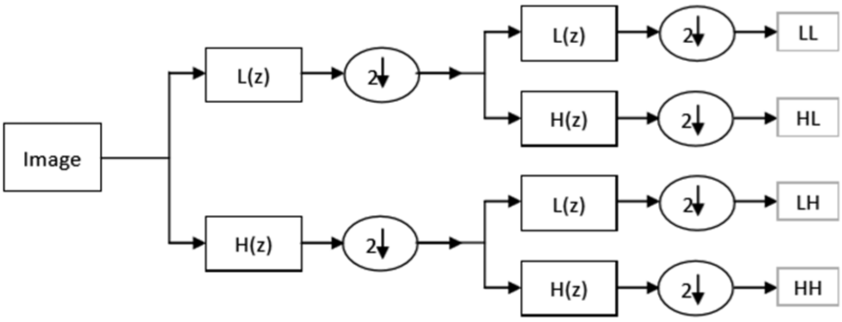

Figure 1.11 Filter bank for one level sub-band decomposition using 2D-DWT

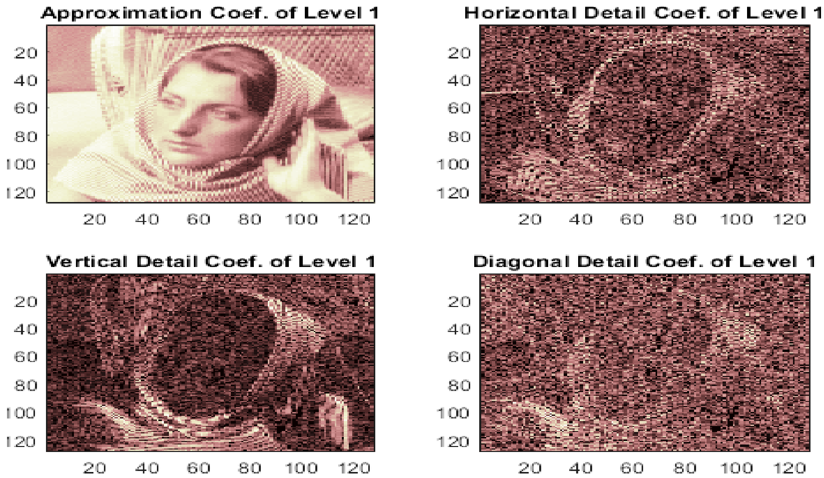

Figure 1.12 2D-DWT applied on input Barbara image illustration of output decomposition of Barbara image

1.1.9 Wavelet-based image coding algorithms

Even though the utilization of wavelet transform in image coding was reported in the literature [43], [44], but EZW [45] has laid the foundation for wavelet-based efficient embedded image coders, SPIHT is the more efficient and advanced version of EZW and has been very popular. SPECK [46] is a block-based image coder, which has less complexity and memory requirement than set partitioning in hierarchical trees (SPIHT). Since then, many wavelet coders were proposed in the literature [47], [48], it is exhibited that for weight and transmission, utilizing JPEG is more inefficient than while transmitting the image without weight. In [49], it has been inferred that SPIHT gives the most vital coding capability while achieving the best deal between the nature of reproduced image and vitality utilization.

What's more, SPIHT is favored over EBCOT coding for equipment execution [50]. Spot coders in view of its ease, coding profitability, and low memory is an increasingly suitable applicant among the wavelet-based inserted coders for utilization in WMSN and VSN [51]. A little memory rendition of the Spot picture coding calculation is needed for resources such as handheld sight and sound contraptions and VSN/WMSN [52]. In this context, we present an audit of various cooperative communication strategies and cooperative image transmission methods. The recent image-coding standard JPEG 2000 is based on DWT, due to its compression efficiency among various other features. Both EZW and SPIHT are tree-based coders, while SPECK is a block-based coder. A low-complexity implementation of SPECK, called SBHP [53], has been included in the framework of JPEG 2000.

The Joint photographic experts' group in 2000 (JPEG 2000) [54], [56], is the consistent image weight standard reliant on the wavelet transform and was created by the Joint Photographic Specialists Get-together advisory gathering in 2000, replacing their DCT-based JPEG standard. The JPEG 2000 is an image compression algorithm which after image tiling (dividing into the rectangular region), these tiles are transformed using CDF 9/7 wavelet transform for lossy weight and CDF 5/3 wavelet transform for lossless weight. This procedure brings about a gathering of sub-groups on different levels. The quantized sub-bands are a piece of code squares. These code squares are encoded, starting from the most fundamental piece plane to the lower bit planes using the EBCOT [57], algorithm. Encoding of each bit plane consists of three passes; Significance Propagation, Magnitude Refinement, and Cleanup pass. Significance propagation pass encodes bits and signs of insignificant coefficients with significant coefficient as neighbors. Then magnitude refinement encodes refinement bits of coefficients found significant in earlier bit planes. Lastly, in cleanup pass coefficients without any coefficients found significant in earlier bit planes are encoded.

Finally, the bits conveyed in the engineering pass are then encoded by a setting-based two-fold calculating coder. The resultant bitstream is then parted into packets containing bits of a social occasion of code squares. Bundles containing less necessary bits might be discarded. Packets from all sub-groups are then assembled in “layers,‟ so that the image quality increases with interpreting of each layer, supporting novel transmission along these lines [58], [59]. The JPEG 2000 encoding count is amazing and has numerous appealing highlights. Be that as it may, it is complicated and computationally strange and has limited embeddedness [60].

1.2 The objective of the thesis

This investigation aims to design a secure and energy-productive helpful image information transmission strategy over wireless channels in WSNs with cooperative communication and MIMO system models. The focus is on image quality improvement in the transmission from source to the destination node via a relay node. The primary objectives of this thesis are given ahead.

- To present a detailed study on the working of cooperative data communication in wireless sensor networks.
- To present the energy analysis and consumption factors for image data transmission in visual sensor networks.
- To display different image compression methods study along with the objective concerning processing time and power requirements.
- To study the literature review of cooperative image transmission methods in WSNs.
- To design the novel security and energy-efficient cooperative image transmission method with additive white of Gaussian noise (AWGN) channel approach.
- To implement and evaluate the proposed approach in terms of different sets of performance metrics.
- To design a one-way cooperative communication system model over Rayleigh fading channel using new algorithms for image transmission and evaluate its performance.
- To design a novel system model of one-way communication in the MIMO designed module.

- The security method designed as per the functionality of one-way communication in MIMO.

The scope of the thesis is investigation, problem analysis, methodology design, and practical evaluation of security algorithms to use encryption and decryption, energy efficiency and cooperative image transmission over wireless sensor systems, The literature study on image transmission over WSNs should be studied in-depth, different algorithms of image compression, channel coding, etc. should be studied. The problem identification of recent methods should be made. The importance of image security and denoising, as well as efficient methods designing for the same, is also a major scope of this thesis. Further, existing algorithms and assumptions found in the literature on cooperative image wireless communication systems, and especially in image data transmission, are explored.

1.3 Hypothesis

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

The goal of this thesis is to present secure, energy-efficient, and robust cooperative image transmission over the wireless sensor systems utilizing novel techniques and techniques with different system models of communications. The key contributions are summarized ahead.

Wireless links between nodes of the one-way relay channel rely on the separation between the nodes, way misfortune.

- **Contribution 1:** In the first contribution, we proposed the efficient one-way image transmission technique using the image pre-processing and image compression method. Image quality improvement efficiency is essential in multimedia applications and wireless communications. We proposed a novel technique for preprocessing images based on adaptive and dynamic noise removal and quality improvement for both before compression and after compression. The compression method designed is based on the 2D-DWT technique. For cooperative communication, the DF methodology is used.
- **Contribution 2:** Image transmission over WSNs impacts two key performance metrics severely: processing delay and power consumption. The image compression method is widely used and discussed in the literature. In the second contribution, we will design the novel, scalable, and efficient image compression and decompression method by using techniques under the transform domain. Also, security is another big challenge to protect the compressed data in the wireless area. To address the security challenge, the elliptic curve cryptography (ECC) based lightweight cryptography technique is designed. The one-way model consists of compression/decompression and encryption/decryption of image data.
- **Contribution 3:** The system module based one-way image transmission in MIMO of digital image transmission over WSNs with aim of compressive sensing (CS) based energy efficiency and image data security.

The thesis consists of a total of five chapters.

In this chapter, Literature Survey, the survey starts with a cooperative image transmission framework and designs followed by a study of different image compression algorithms and coding techniques. The image cryptography algorithm is described after that. Finally, the review of state-of-the-art methods on cooperative image transmission, new compression methods, security algorithms, objective and hypothesis are shown. The design of algorithms for the first contribution.

In the second chapter," Efficient One-Way multi-hop cooperative Image Transmission over WSN," the design algorithms are presented. The simulation environment and images data set are described in the chapter, along with simulation results.

In the third chapter, "Energy-efficient secure one-way cooperative image transmission over WSN," the newly designed compression and cryptography algorithms for energy efficiency and image quality improvement and simulation results are presented.

In the fourth chapter, "One-way image transmission using MIMO model," the final contribution is proposed along with its simulation results and evaluation.

In the fifth chapter, "Conclusion and future work," according to the contributions designed in this research work and their performance evaluations, the contribution presented in this chapter along with the future works.

2

Efficient One-Way Multi-hop Cooperative Image Transmission over WSN

2.1 Introduction

In the previous chapter, different cooperative communication methods that demonstrated their viability in various ways were reviewed. However, there are a few more issues that should be tended to while managing superb image transmission in WSNs, for example, extreme vitality utilization while preparing to proceed with image transmissions, to achieve the trade-off between image quality, and intensity of image transmission. Before presenting the proposed model, this section presents the review of recent and conventional techniques for cooperative image transmission it is exhibited that for weight and transmission, utilizing JPEG is more inefficient than while transmitting the image without weight.

In Section 2.1.1, cooperative communication enhancement is proposed for cooperative diversity and relay selection. In Section 2.1.2, the cooperative image transmission is reviewed. In Section 2.1.3, all other related works, such as image compression and cryptographic methods that are referred to in this research, are examined.

2.1.1 Cooperative communications enhancement

J N Laneman et al. [63] were first to propose the concept of cooperative diversity to efficiently and effectively mitigate the impact of multipath fading in a wireless network across multiple layers. In the seminal work, they have proposed energy-efficient cooperative algorithms and show how to deploy them on various network architectures. These techniques employ a set of devices known as relaying terminals, which provide spatial diversity at the cost of increased complexity, power consumption, and bandwidth utilization.

J N Laneman et al. [64] proposed space-time architecture for a cooperative relaying system with Alamouti space-time block codes. The new system architecture is capable of mitigating multipath fading by exploiting spatial diversity in a cooperative communication system. Authors have demonstrated that the proposed framework architecture achieves a full reasonable variety request and provides higher spectral efficiency benefits than conventional schemes.

E Zimmermann et al. [65] studied the application of cooperative diversity schemes for systems with realistic receivers and limited modulation alphabets. Authors have found that under this situation, to achieve full diversity, adaptive relaying protocols must be used.

J N Laneman et al. [66] analyzed cooperative diversity schemes using fixed selection, and incremental relay selection techniques. Authors have analyzed framework performance as far as outage probability is concerned and found that for all of the cooperative diversity schemes, except decode-and-forward, they achieve full diversity.

2.1.2 Cooperative image transmission

In [67], the authors presented an inventive image-pixel-position data-based asset designation collaboration to enhance image transmission quality with a serious vitality-spending limitation for image applications in WMSNs. Furthermore, it investigates these particularly unique significance levels among image data streams.

In [68], the authors proposed, a methodology was suggested for mystery image sharing on various center points. Different ways for image conveyance were to accomplish high security with no key scattering, and therefore, the key administration-related issues did not exist. The energy productivity was another real commitment made by the authors. This plan did not just enable each image sensor to transmit perfect divisions of verified images through fitting transmission routes crucially and capably but also, gave inconsistent insurance to cover image locales by way of determination and versatile BER necessity.

In [69], the authors introduced a method for employing a collaborative signal upgrade to accomplish energy-proficient image transmissions in WSNs. A community signal upgrade approach was convincing because of its ability to spare individual vitality utilization by spreading absolute transmission utilization over various sensors. Singular parcels portraying an implanted wavelet-encoded image show an essentially inconsistent commitment towards image quality. The system accomplishes the highest conceivable image quality, even in a given limited transmission energy utilization spending plan.

In [70], an energy-aware interleaving algorithm was introduced by the authors to direct blast mishap impacts by spreading out bundles as indicated by each image locale's pre-determined transmission. Trial results exhibit that their method can not merely improve image transmission quality but also extend the lifetime of the visual sensor.

In [71], they proposed a vitality proficient image transmission methodology for remote sensor frameworks which joined wavelet-based image deterioration and cooperative correspondence. With this approach, the authors used selective DF participation, so a hand-off center works together with the source by sending only a lower-objectives adjustment of the first image acquired using DWT. The authors asserted that the proposed SDF-DWT procedure is more capable than non-cooperative technique, additionally defeating the standard SDF systems. Likewise, they stated that the energy efficiency of IDF, without the need for a pointer channel, could be achieved in this manner.

In [72], the authors introduced ideal Viterbi-based complete variety grouping recognition (TVSD) for groundbreaking image/video unraveling in remote sensor frameworks. They proposed a novel plan for robust recreation, given absolute variety regularization, towards image/video correspondence in mixed media remote sensor frameworks. They decided the ideal joint source-channel decoder as the blend of a most extreme likelihood cost work and an anisotropic complete variety standard-based regularization factor. Likewise, it was exhibited that the trellis-based Viterbi decoder can be used for good image entertainment using changed all-out variety state and branch measurements.

In [73], the authors introduced an adaptive forward error correction (FEC) coding and helpful transferred image transmission structure, through which both transmission quality and energy efficiency could be ensured under complex adaptable correspondence channel conditions. This article shows the four critical steps of their approach such as (1) DWT and wavelet-based decomposition, (2) pixel-position (PP) information and pixel-value (PV) information split based unequal image resource allocation, (3) transmission through channel fading and AWGN communication environment, and (4) multiple-relays and adaptive channel coding. The comparative study of their method against the existing methods showed that their approach was more efficient for transmitting astounding images through battery-restricted smartphone platforms.

In [74], the author developed the vitality-effective image transmission approach in remote multimedia sensor systems. In this approach, image transmission over multibounce WSN was demonstrated to be feasible, utilizing a combination of vitality-productive handling architecture and a reliable application layer convention that diminished packet mistake rate as well as re-transmissions.

In [75], the author proposed a novel item: a closeness model and image transmission plan for WMSN. The proposed arrangement was assessed dependent on in-center imperativeness usage and reproduced image with peak signal to noise ratio (PSNR). Re-enactment results of this method claimed that the proposed methodology spared 95% of the center point essentialness with the obtained picture PSNR of 46 dB when contrasted with another cutting edge approach.

In [76], the most recent approach for productive image transmission over Zigbee-based image sensor frameworks is shown. The authors introduced two image transmission methodologies that are driven by unwavering quality and constant deliberations to move JPEG pictures over Zigbee-based sensor frameworks. By including two bytes counter in the header of the information parcel, they effectively handled the rehashed information brought about by the re-transmission component in the conventional Zigbee framework layer. They structured a productive re-transmission and affirmation instrument in the Zigbee application layer. By grouping different information-gathering occasions, they furnished information parcels with differential responses and assurance that image bundles can be moved promptly even with an enormous number of re-transmissions. The experimental outcomes led to the claim that making an image program over Zigbee-based sensor systems is effective.

In [77], the authors examined the various approaches for information dependability, transmission, and weight for correspondence in remote sensor frameworks. In [78], [79], mention is made of some past works about image and data transmission techniques for WSNs. The systems examined demonstrate their adequacy in various ways; in any case, there are as yet a couple of pitfalls which need to be addressed while dealing with brilliant cooperative image transmissions in WSNs, for example, over the top vitality utilization while preparing proceeds with image transmissions to achieve the trade-off between image quality and generosity of image transmission. Different image filtering procedures are accessible and assessed in image handling [80], [81]. In [82], the investigation over the various image compression methods to minimize the energy consumption, computational efforts, and enhancing the image quality and coding for sensor network communications is presented. In [83], a new framework is suggested for WMSN in which the algorithm for disseminated image compression proposed to lessen the vitality utilization of sensor hops while transmitting the images. In [84], a recent study investigated the advantages of a cooperative image transmission approach compared to conventional orthogonal methods for future wireless sensor networks. This study detailed how to use cooperative transmission models such as DF and AF based on experimental investigations. Other Recent Methods In [85], the authors mentioned that the estimation number for CS entertainment decreases monotonically with the reduction of weight rate. To keep the image not extraordinarily augmented, the compression rate must be a little esteem. In this way, with the decrease of the estimation number for the CS propagation, it isn't possible to correct inserted data and recoup a unique image.

In [86], the authors portrayed a technique in light of the fascinating properties of an orthogonal matrix utilizing the Gram-Schmidt calculation. During the time spent in block-wise arbitrary change, the calculated guide was utilized, followed by the dissemination procedure. The idea of spatio-temporal confusion can additionally enhance the security effectiveness of the plan, a joint source-channel rate portion combine that boosts the level Rayleigh fading channel utilizing contributions of binary phase-shift keying (BPSK) and Gaussian was investigated. The framework raises the optimization in PSNR proportion and the BER execution is better when the number of sub-carriers is increased. The conventional methods reported for image quality improvement need to redesign while considering the requisite for less processing time and power requirements at sensor nodes.

In this chapter, the first research contribution is proposed in which one-way cooperative image transmission over AWGN channels is designed. The key highlights of this contribution are:

- In this algorithm, to improve the quality as well to preserve the originality of image contents, we used two image filtering techniques such as Laplacian and average filtering at the transmitter, and we proposed a hybrid threshold-based wavelet denoising function in the receiver end.
- Design of DWT-based image compression technique with the target of noise suppression, *1D-DWT*, the source image s of size N is divided into two coefficients such as approximation coefficients CA_1, and detail coefficients CD_1, at the transmitter, we compressed the pre-processed image using 2D-DWT. 2D-DWT is widely used in image processing applications. This method performs the decomposition of approximation coefficients at level j in four components.
- We are applying the proposed methods to the cooperative communication model using the AWGN channel with the inclusion of the modulation techniques.
- Only the approximation coefficient is used for modulation and demodulation to minimize energy consumption.
- The approximation coefficient used for the modulation and demodulation process due to the fact that it contains more important information *than other* coefficients of the wavelet transform. *Modulating and* demodulating *the* approximation coefficient achieved an effective solution.

- Inverse fast Fourier transform (IFFT) and fast Fourier transform (FFT) activities performed at the other three coefficients of DWT at the transmitter and receiver ends to reduce processing time and energy as well.
- The execution assessment and close performed at the other three coefficients of DWT at the transmitter and recipient end to control time and imperativeness too, after modulated data is then converted into time/space form using IFFT operation at transmitter node. At the receiver node, the received data is converted to space/time form using FFT operation.
- The execution evaluation and close assessment against the condition-of-workmanship structures for pleasant image transmission for examination against the state-of-workmanship frameworks for cooperative image transmission for a one-way communication model.

In Section 2.2, the proposed methodology, system design model, and algorithms are introduced. In Section 2.3, the simulation environment in which the background about the simulation tool, experimental requirements, data set, and performance metrics are described. In Section 2.4, the reproduction results and similar examination are displayed. In Section 2.5, a summary of the contribution is presented.

2.2 Methodology and System Design Model

Figure 2.1 demonstrates the proposed one-way multi-hop cooperative image transmission system model for wireless networks. The transmitter (T) plays out the image quality improvement first and then the image is compressed using the 2D-DWT technique. Finally, the modulation and IFFT operation are performed on a compressed approximation block of the image. The image packets are forwarded to relays over AWGN remote channel. At the relay nodes (Rn), the strategy is used. At the received node (D), all process is performed in a switched way so as to remake the first image transmitted over the wireless cooperative system.

To transmit the image beneficially through the system, each relay node in the system has two roles to perform: relaying role (RR) and monitoring role (MR). Each relay node ought to have two parameters mentioned in eq. (2.1) and (2.2).

The equation (2.1) displays the set of RR node that is in charge of relaying the information starting with one relay node, then onto the next in a multihop wireless communication

$$RR = \{r_i \mid r_j , M_j, d_{i\,j} \}, \tag{2.1}$$

where r_i is the ith relay node, r_j is the *jth* relay node, M_j is all out sender and recipient nodes associated with *ith* relay node, and d_{ij} is the distance between the *ith* and the *jth* relay node that is represented by Equation 2.2 showing the set of monitoring role (MR), relay node, which is in responsible for detected and transmitting the present blocks to the nearest Rn. Relay node then detects the got information, applies the DF technique, and then transmits towards the next intermediate of the road Rn or the destination node

$$MR = \{M_j \mid r_i, d_{i,j} \}\ i \neq\ j, \tag{2.2}$$

Where M_j is the *jth* MR node, r_i is the *ith* relay node connected to the *jth* MR node, and $d_{i,j}$ is the distance between the *ith* MR node and the *jth* RR node.

Each relay node that appears in Figure 2.1 either goes about as an RR node or MR node according to the current transmission requests. Figure 2.1 is additionally deteriorated in different algorithms depicted ahead.

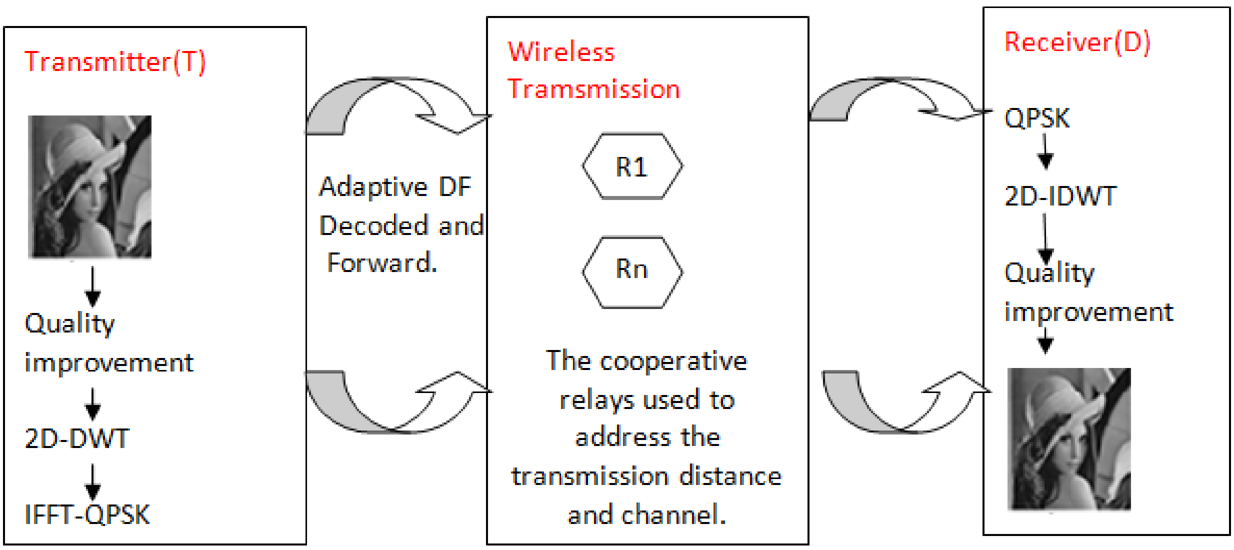

Figure 2.1 One-way cooperative image transmission models over the AWGN channel

In algorithm 1, the input image is received either at the transmitter to transmit over the wireless network or at the receiver received from the transmitter. The objective of algorithm 1 is to improve the quality of the image which may be degraded due to different illuminations conditions either at capturing devices or in the wireless transmission channels. In this algorithm, to improve the quality as well to preserve the originality of image contents, we used two image filtering techniques such as Laplacian and average filtering.

Algorithm 1: Quality (I)
Inputs: I = Image captured by *T*, α = 0.2, default alpha value μ = [2 2], default size Output: Improved image *P*
1. Select frame I 2. Grayscale conversion 3. Design filter 1 P_1 = filter ('laplacian', α), using eq. (2.3) & (2.4). 4. Design filter 2 P_2= filter ('average', μ) 5. P = P_1-P_2 6. Return (P)

The Laplacian of information image features the regions of critical force change in image. This Laplacian strategy is as often as possible utilized in image smoothing operations to limit noise sensitivity. This capacity takes a grayscale (2D) image as info and produces the sifted grayscale (2D) image as yield. The Laplacian LF (p, q) of an image with pixel intensity value I (p, q) is given by:

$$LF\ (\mathrm{p},\mathrm{q}) = \nabla^2\ \frac{\partial^2 \mathrm{I}}{\partial \mathrm{p}^2} + \frac{\partial^2 \mathrm{I}}{\partial \mathrm{q}^2}. \tag{2.3}$$

Where ∇^2 shows the convolution filter and ∂ sigma value used to configuration filter in the scope of 0 to 1 as it was. The p and q address image pixels position. The convolution channel on the data image is given by:

$$\nabla^2 = \frac{4}{\alpha+1}\begin{bmatrix} \frac{\alpha}{4} & \frac{1-\alpha}{4} & \frac{\alpha}{4} \\ \frac{1-\alpha}{4} & -1 & \frac{1-\alpha}{4} \\ \frac{\alpha}{4} & \frac{1-\alpha}{4} & \frac{\alpha}{4} \end{bmatrix}. \tag{2.4}$$

After Laplacian filtering, next, we applied an average filter on the input image. This method is called mean filtering. The average filter is a simple spatial filter based on a sliding-window which substitutes the center value in the window with the approximate value of the pixel in that particular window. The results of both filters are subtracted to get the final pre-processed image.

Algorithm 2 shows the transmitter end structure in a multi ricochet pleasant image transmission process. As shown in calculation 2, after pre-getting ready, we need to perform image weight. For this, the 2D-DWT technique is utilized and spoken about in the passages ahead. We want to use the 2D-DWT over the 1D-DWT in this work. The advantages of using 2D-DWT over the 1D-DWT are explained ahead:

Algorithm 2: Transmitter (I)
Inputs: Rn = R_1, R_2 … R_i (Relay Nodes) T = Transmitter node D = Received or destination node I = Image captured by T W_{name} = 'HAAR' Output: Transmitted Blocks {I_1, I_2, I_3, I_4}
1. Get current frame I 2. P = Quality (I) 3. [cA,cH,cV,cD] = 2D_DWT (P, Wname) 4. Perform QPSK modulation cAm = mod (cA, QPSK) 5. D = {cAm, cH, cV, cD} 6. Perform IFFT operations {I_1, I_2, I_3, I_4} = ifft (D) 7. Get the packetize {I_1, I_2, I_3, I_4} 8. Transmit the current blocks through AWGN channel 9. AWGN {I_1, I_2, I_3, I_4} 10. Return (I_1, I_2, I_3, I_4)

In *1D-DWT*, the source image s of size N is divided into two coefficients such as approximation coefficients CA_1, and detail coefficients CD_1. This can be achieved using convolving operation on s using Lo_D (low pass filter) for approximation and Hi_D (high pass filter) for detail. Then dyadic decimation is applied.

The length of each coefficient is.

$$[(N-1)/2] + L. \tag{2.5}$$

where N is the length of the image, and L is the width of the image. As 1D-DWT is only a single level compression technique, it is vulnerable to image data loss, and along these lines, 2-D DWT is used. In multi-hope remote image transmission frameworks, we need an effective information compression technique with the least information misfortune probabilities. In this manner, at the transmitter, we compressed the pre-processed image using 2D-DWT. The 2D-DWT is widely used in image processing applications. This method performs the decomposition of approximation coefficients at level j in four components: the approximation at level j + 1, and the details in three orientations (horizontal, vertical, and diagonal). Figure 2.2 is explaining the process of DWT for 2-D. This compression results in four blocks of the input image. At the receiver end, the decompression operation is performed by inverse 2D-DWT. As the name indicates, the inverse 2D-DWT reconstructs the original image from four input coefficients received.

After compression of the image, next, we have to perform the quadrature phase-shift keying (QPSK) modulation sought after by IFFT operation at the transmitter center point. QPSK is used at the transmitter side. The measure of radio recurrence range required to transmit QPSK dependably is a large portion of that needed for binary phase-shift keying (BPSK) signals, which thus prepares for more clients on the channel. Hereafter, the QPSK modulation technique is utilized in this work. At the receiver end, demodulation is performed using the QPSK demodulation framework on obtained image data. As the approximation coefficient contains more details of compressed DWT image, we applied the modulation of the approximation coefficient only and transmit the other coefficients in compressed form along with modulated approximated coefficient over the wireless channel towards the receiver. The modulation data is then changed over into time/space structure using IFFT operation at the transmitter node. At the receiver node, the obtained information is converted over to space/time structure utilizing FFT operation. The Fourier analysis used to convert the signal from its original domain (often time or space) to a representation in the frequency domain and vice versa. The image data is then transmitted over the wireless AWGN channels with the possibility of noise insertion.

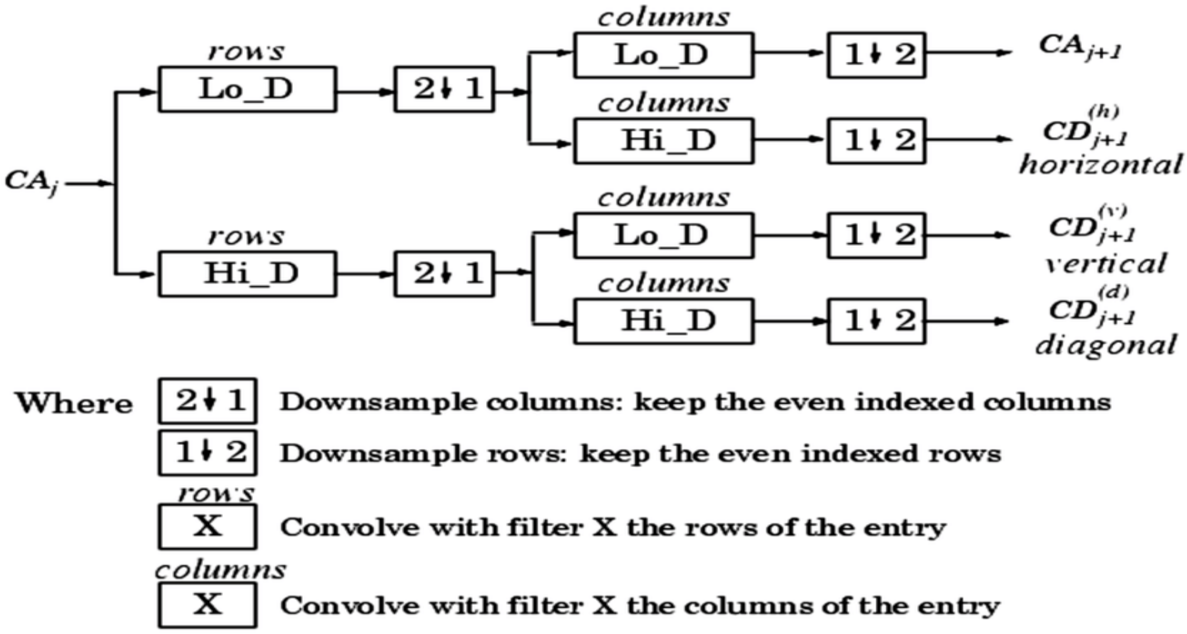

Figure 2.2 2D-DWT decomposition

Algorithm 3 demonstrates the working at each relay node, which is dependent on the versatile DF method. Each relay node either goes about as the RR focus point or MR focus point during the image transmission process. The blocks detection is performed by the DF method utilizing equations 2.6 and 2.7. The detection function of the *DF* method can give as:

$$f_{DF}\ (O_{SR}) = r^{\wedge} \tag{2.6}$$

Where $r^{\wedge}$ denotes the decoded/detected data at the relay node, O_{SR} represents the original data submitted from source S to receiver R for function f_{DF}. For QPSK modulation DF detection function can be given as:

$$f_{DF}\,(O_{SR})=sgn(O_{SR}). \qquad (2.7)$$

Where sgn (.) is the Signum function. The detection function reliant on got data O_{SR} and does not have any data about the idea of the S-R channel. If the blocks are detected successfully at each relay, then FFT is performed on all DWT blocks except the approximation block. The demodulation is performed on the estimation square. After demodulation, we associated the wavelet denoising on theory square to cover the bustle from the image data (which may happen because of the different network conditions). This method is associated with the estimation coefficient as it contains a large amount of data than other DWT coefficients. The technique for wavelet denoising is mentioned ahead.

Let's suppose I_1 is approximation coefficient detected and demodulated at the relay node there is noise $N_{R.}$ inserted in I_1 while passing through the wireless channel towards relay node R. Then the resulted approximation coefficient at R node is:

$$I_1^R = I_1 + N_{R.} \qquad (2.8)$$

Where, I_1^R is the uproarious surmise coefficient at current relay node R. Therefore, to suppress the noise from the original coefficient, we have to perform the thresholding based noise removal. There are two types of thresholding functions, such as hard thresholding and the soft thresholding for wavelet denoising. We proposed hybrid threshold-based wavelet denoising function can be defined as:

$$\widetilde{I_1^R}(i,j) = \begin{cases} sgn\,(I_1^R(i,j)) * \left(\left|I_1^R\,(i,j)\right| - \alpha\right), & \text{if } (\,I_1^R\,(i,j) > \varepsilon\alpha) \\ 0 & \text{else} \end{cases}. \qquad (2.9)$$

Where α is the minimum threshold value for suppressing the noise, ε is the extra adjustment factor in a range of $0 < \varepsilon < 1$, and $I_1^R\,(i,j)$ is the current value of the noisy approximation coefficient at the location (i, j). if the detection of blocks failed, the present blocks are discarded to prevent the image data loss. On advancement, the re-modulation and IFFT activities are performed and transmitted to the next node. The final demodulation of the modulated approximation coefficient performed only at the receiver node. Thus at the relay, the modulated data is again re-modulated and transmit towards the next node.

Algorithm 3: Relay (I_1, I_2, I_3, I_4)
Inputs: Rn = R1, R2 … Ri (Relay nodes) In = I_1, I_2 … I_i (Received blocks) Output: Transmitted blocks {I_1, I_2, I_3, I_4}
1. **FOR** each Rn 2. Detect received blocks using Eq. (2.6) & (2.7) 3. **IF** (detect == true) 4. {I_2, I_3, I_4} **=** fft (In {2, 3, 4}) 5. I_1 = demod (In{1}, QPSK) 6. Apply wavelet denoising on I_1, Eq.(2.9) **7. ELSE** 8. discard (In) 9. break **10. END IF** 11. Re-modulation 12. I_1 = mod (I_1, QPSK) 13. F_r = {I_1, I_2, I_3, I_4} 14. AWGN {F_r} 15. **END FOR**

The process is repeated among all the relays; still, the proposed receiver receives all the image blocks. The process at the recipient node is clarified in Algorithm 4 ahead. At the receiver node, achieve reverse *DWT* to reconstruct the image from the received blocks. To suppress the noise inserted in wireless data transfer phase, we again applied the algorithm 1 to improve the received image quality.

Algorithm 4: Receiver (I_1, I_2, I_3, I_4)
Inputs: $F_r = I_1, I_2 \ldots I_i$ (Received blocks) Output: I_r = received image
1. I_1 = demod (F_r {1}, QPSK) 2. R = IDWT (I_1, I_2, I_3, I_4) 3. I_r = Quality (R) 4. Return (I_r) 5. STOP

2.3 Simulation environment

2.3.1. Dataset

For image transmission in a cooperative wireless communication system, we used the MATLAB images data set for performance evaluations. We experimented on a total of sixty-five images from the book Digital Image Processing (DIP) Images. Table 2.1 shows some of the sample images from this data set.

Table 2.1 Dataset examples of DIP book images

Lena	
Camera_Man	
Man	

Ship	
Barbara	
Couple	

2.3.2 Performance metrics

To assess the exhibition of the proposed model, we consider both image quality evaluation parameters and data rates evaluation metrics such as bit error rate (BER), PSNR, Mean Square Error (MSE), and transmission time.

BER: BER is the number of bit errors per unit time. The BER is the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, partitioned by all dwarf moving bits during an examined time. It is computed as:

$$BER = N_{err}/N_{bits.} \quad (2.10)$$

Where N_{err} is the number of bits detected error using whole blunders, and N_{bits} is the total number of bits sent.

MSE: The mean square error between the original image transmitted from the transmitter and received imaged the receiver is computed as:

$$MSE = \frac{1}{M*N}\sum_{m=0}^{M-1} \sum_{n=0}^{N-1}[I_1(m,n) - I_2(m,n)]^2. \quad (2.11)$$

Where $\mathrm{I_1(m,n)}$ is the pixel values of the input image T and $\mathrm{I_2(m,n)}$ is the pixel values of the received image D, and M, N are dimensions of the images.

PSNR: PSNR is computed using the MSE. The PSNR between the original image transmitted from the transmitter and received image at the receiver can be given as:

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{\mathrm{R}^2}{\mathrm{MSE}}\right). \quad (2.12)$$

where R is the peak pixel value input image is 255

2.4 Simulation results

Per the objective of this contribution, the one-way cooperative image transmission model is designed and evaluated over the AWGN channel. We also present the reproduction results and their relative examination with ongoing systems and recent techniques. The parameters (BER, PSNR, MSE) described above are considered for performance evaluations. The energy efficiency is out of the scope of this contribution and will be focused on in the next chapter. Before presenting the evaluations, we offer the transmitter and receiver activities while performing image transmission.

Figure 2.3 Original image at the transmitter

At the transmitter node, the input image (Figure 2.3) is first processed by applying Algorithm 1 in which the filtering is performed to improve the quality of the image before the transmission (Figure 2.4). After the pre-processing, the DWT-based image compression technique is applied in which the four coefficients are extracted as shown in Figure 2.5.

Figure 2.4 Pre-processed image at the transmitter

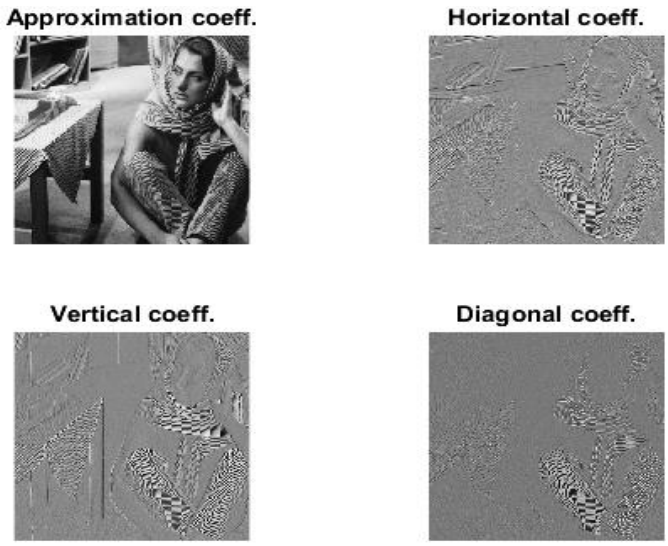

Figure 2.5 Image compression using DWT

Each compressed coefficient of the image is further applied for modulation and transmitted over the noisy wireless channel through the cooperative relay communications using the DF technique. At the receiver end, all noisy image blocks are received and the first decompression applied. Figure 2.6 shows the output of the decompressed version at the receiver end.

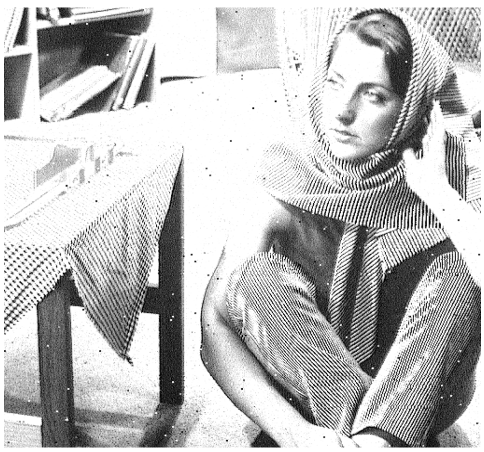

Figure 2.6 Decompressed image at the receiver end

Figure 2.7 Pre-processed final image received at the receiver end

After the decompression and demodulation, we receive the original image at the receiver end. However, due to noisy wireless, the quality of image degrades. Therefore, we connected the pre-processing algorithm to improve the nature of the picture at the receiver end. Figure 2.7 shows the final image received. Table 2.2 shows the outcome of other images in the dataset.

Table 2.2 Transmitted and received images using the proposed model

Image Name	**Transmitted Image**	**Received Image**
Barbara		

Camera man		
Lena		
Couple		
Man		

The results for the above images are measured in terms of PSNR, BER, and processing time represented in Table 2.3 below. Here, the number of relaying nodes is assumed to be 25.

Table 2.3 PSNR, BER, and Processing time values

Image Name	**PSNR (dB)**	**BER**	**Processing Time (S)**
Barbara	50.01	0.00231	0.78
Cameraman	37.3	0.0023	0.79
Lena	53.46	0.0024	0.75
Couple	58.58	0.0022	0.81
Man	58.69	0.0023	0.79
Average	51.6	0.0023	0.784

The compared the results of the proposed methodology with state-of-art comparative strategies for the most part for the picture quality analysis. Table 2.4 shows the average PSNR comparative analysis. Here, the number of relaying nodes is assumed to be 25.

Table 2.4 Comparative analysis of average PSNR results

Algorithm	**PSNR (dB)**
Lecuire et al. [2]	31
Nasri et. al [14]	20
Yasar Abbas et.al [80]	46
Proposed Method	51.6

Table 2.3 displays the results estimated for the proposed work for various images from the transmitter end. The outcomes are improved and have gainful image quality, with breaking focuses on BER rates with the least preparation time. The near investigation regarding PSNR values is performed with the state-of-workmanship techniques shown in Table 2.4. The results show that the developed procedure improves all the conditions of workmanship techniques exhibited in the past. On the off chance that the PSNR results demonstrate the improvement, at that point, BER is additionally improved for the proposed technique as a look at state-of-craftsmanship image transmission strategies show. The result of PSNR is improved using the proposed method because of using wavelet denoising as well as separate noise filtering functions at the transmitter and receiver. Figures ahead demonstrate the diagrams for various arrangements. The consequences of Table 2.4 are reflected in Figure 2.8.

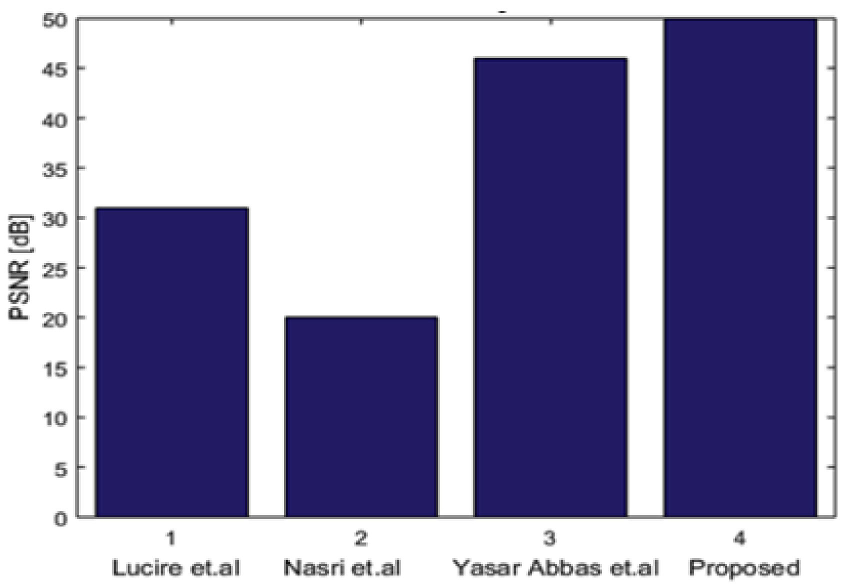

Figure 2.8 Average PSNR comparative results

In Figure (2.9), the PSNR and number of intermediate nodes result at each relay node which is increasing from 1 to 25. If the number of intermediates nodes rising, then the image quality of transmitting is reduced. Our proposed method showing better performance in both graphs, as it was expected PSNR should be more and MSE should be minimum.

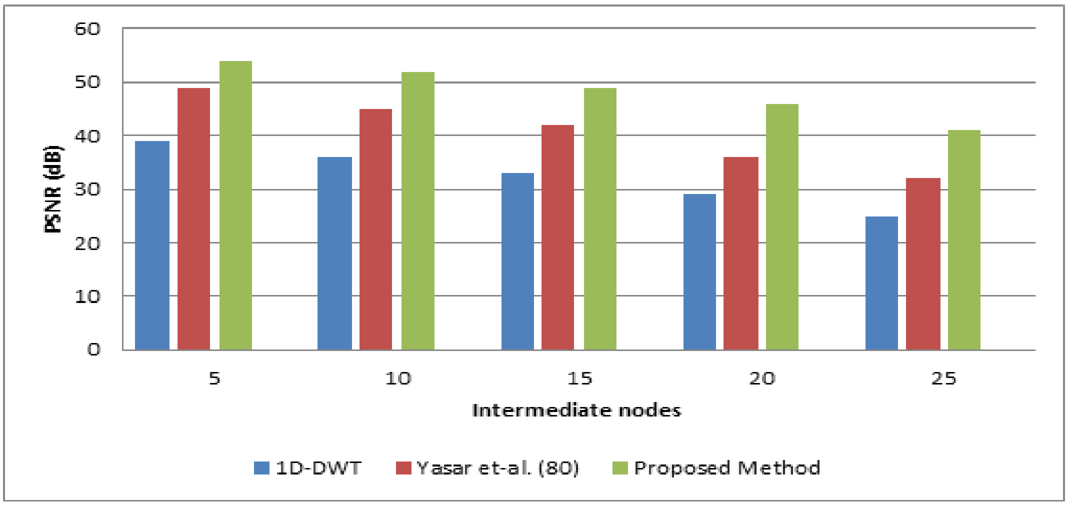

Figure 2.9 PSNR versus intermediate nodes

Similarly, the BER result of the proposed system shows that for each SNR level, the performance of BER is less as compared to state-of-the-art solutions, as shown in Figure 2.10. As observed in Figure 2.10, the proposed methodology of helpful picture transmission utilizing the QPSK modulation method shows minimum BER as compared to the 1D-DWT compression technique and methodology. The performance shows improvement in image quality as well as the data rate using the proposed model of this chapter.

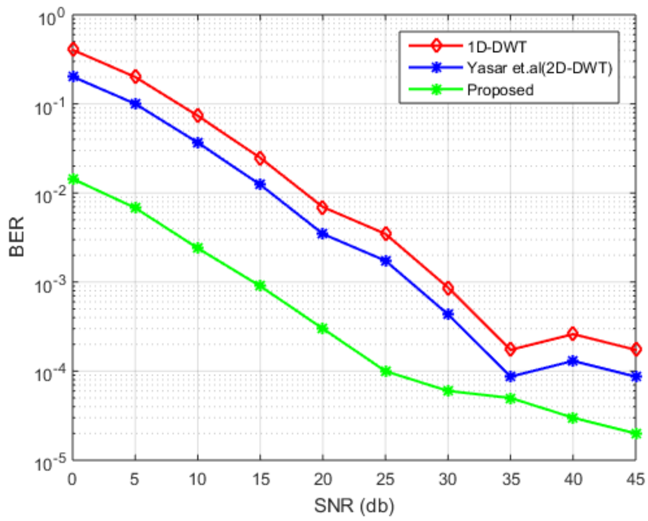

Figure 2.9 BER performance of the proposed system when the number of relaying nodes is 25

2.5 Summary

Contribution 1 of this thesis is towards the one-way efficient cooperative image transmission designed and evaluated in this chapter. We designed the multi-hop cooperative image transmission with the primary target of image quality performance improvement over the wireless sensor nodes. The image transmission is performed over the channel from transfer to transmission nodes from these nodes to the deliberated receiver node. At relay nodes, the adaptive DF technique is used to detect, decode, re-encode and forward over the AWGN channel. The results of PSNR and BER are compared with previous methods. There is a significant improvement in image transmission performances using the proposed method. However, the challenge of secure transmission and energy efficiency does not consider.

3

Energy-Efficient Secure One-Way Cooperative Image Transmission In Rayleigh Fading Channels over Wireless Sensor Networks

3.1 Introduction

In Chapter 3, the first contribution of cooperative image transmission is designed and evaluated with the main aim of improving the image quality with minimum processing time and error rates. However, for wireless multimedia sensor networks (WMSNs), energy efficiency is also important to research challenges as the high dimensional digital images consume more processing capabilities of sensor nodes. In WMSN, the image is transmitted through a large number of relays, thus the larger the transmissions the more the energy consumption. The use of compressive sensing (CS) for periodic data transmissions is proven as an effective solution for WSNs. CS-based sensor communications reduce data transmissions and improve energy efficiency significantly. But another challenge while using the compression is data loss due to different security threats during the transmission. The compressed data at the receiver end is decompressed with poor quality, hence securing the compressed data by using the lightweight security method is important while planning the helpful picture transmission model. In this chapter, we propose our next research contribution to alleviating the challenges of security and energy efficiency for cooperative digital image transmission. The key highlights of this contribution are:

- Optimized JPEG 2000 introduced for the digital image compressed after the denoising to improve the image transmission performance as well as computational efficiency.
- The optimized elliptic curve cryptography (ECC) technique further encrypts the compressed data. The novelty of this method is that it achieves the trade-off between minimum energy consumption and strong security by modifying the optimized scalar multiplication tasks using a special random

number as a scalar. This approach limiting the computational endeavors accomplishes higher security for compressed data.

- The complete wireless communication model designed using the BPSK modulation over a Rayleigh fading channel for cooperative image transmission.
- We have investigated image compression algorithms using image quality analysis elements like PSNR, MSE, etc.
- Performance evaluation of cooperative image transmission with best-in-class techniques exhibited as far as BER, MSE, energy efficiency, etc. are concerned.

Before presenting the proposed methodology design and algorithms, we first discuss the different types of digital data and file types that are transmitted over the WMSNs. Also, the various security threats are discussed in Section 3.2. Section 3.3 presents the proposed methodology. Section 3.4 presents the simulation results. Section 3.5 presents a summary.

3.2 Multimedia Data and Threats

The term ‘data’ now has a specific meaning due to the wide use of computers and networking. It means the information that is stored in digital form, such as the contents of a computer’s memory [90]. The data across networks are available in a series of bits – zeros and ones. These series are meaningless unless their classification formats are known. Therefore, the information in the field of computers and networking are classified according to the nature of the data, for example, content, image, video, and audio [91]. In computer memory, each class is distinguished from the others by extension of its titles (e.g., .TXT, .TIF, etc.).

3.2.1 Digital Data Types

A. Digital text

The text has a dual nature: it is a visual portrayal of language and a realistic component in its own right. It is an accumulation of characters sequenced to give a certain meaning [92]. This meaning may express language, including all writing symbols. These characters and symbols are coded to the zeros and ones using the famous coding method ASCII (American Standard Code for Information Interchange) [93]. The substance record is utilized to contain '.TXT' extension or '.PDF' if it is compressed to reduce file size to be suitable for transfer over networks.

B. Digital image

An image is a two-dimensional capacity that speaks to a proportion of some trademark, for example, brilliance or shade of a scene. An advanced image is made out of image components called pixels [94]. Pixels are the littlest example of an image. A pixel speaks to the brilliance at one point. Because of the huge size of the digital image, the compression method is used to lessen its size. According to the compression technique, the image extension will be matching (e.g., '.JPG').

3.2.2 Digital image processing

The term 'digital image processing' (DIP) alludes to the control of an image by various methods for a processor. The various components of an image-handling framework incorporate image securing, image stockpiling, image preparation, and show. A digital camera is a famous device known to capture digital images [94]. It represents a complete image processing system [95]. An image is a 2D (two-dimensional) portrayal of a 3D (three-dimensional) scene. A digital image is fundamentally a numerical portrayal of an item. The modern image is made out of a set number of segments, all of which have a particular location and value. Pixel is the term most broadly used to mean the parts of an advanced image. The digital image technologies offer many useful advantages such as:

- Image processing becomes faster and cheaper.
- Easier storage and transmission.
- Facility of displaying images before and after shooting operation.
- Copying an image several times while retaining high quality.

On the other hand, there are some drawbacks of digital images that are:

- Misuse of copyright has become easier.
- The memory required to store digital images is very high.

❖ Real-time implementation of digital images needs a very fast processor because the volume of data is enormous.

A. Digital image file formats

Images can be broadly classified under four categories:

(i) Binary images (Black and white);

(ii) Grayscale images;

(iii) Colour images; and

(iv) Multispectral images.

A binary image takes only two values to represent pixel brightness gradation, either zero or one. Grayscale image contains only brightness information. Each pixel value in grayscale corresponds to an amount of light, and Each pixel is considered a byte, so the brightness varies between ('0' = 'Black') to ('255'= 'White'). A color image has three values per pixel which measure the power and chrominance of light. Each pixel is a vector of shading parts. Primary shading spaces are RGB (red, green, and blue), HSV (hue, saturation, and value), and CMYK (cyan, magenta, yellow, and black) [96]. Multispectral images of a similar article that was taken in various bands of the unmistakable or infrared locale of the electromagnetic range. These images ordinarily contain data outside the normal human perceptual range. The categories mentioned above of digital images are stored in digital systems so they need to be created in suitable document designs [97]. A record configuration is a technique used to store advanced information and distinctive document organizations exist for putting away images. Formats exist for storing images. The digital image file format consists of two parts:

(i) File Header, and

(ii) Image Data

The file header contains some of the vital information like format or version identification, width and height of the image, kind of image (binary, grayscale, color image), and image data format, which determines the request wherein pixel values are stored in the image information segment. The header also specifies the type of compression mechanism. The length of the file header is often fixed. The header data must give all the essential data to reproduce the first information and its association from the stored information [99]. The most common image file formats are:

- GIF (Graphics Interchange Format).
- JPEG (Joint Photographic Expert Group).
- PNG (Portable Network Graphics).
- TIFF (Tagged Image File Format).
- BMP (Microsoft Windows Bitmap).
- PSD (Photoshop's Default Format).
- EPS (Encapsulated PostScript).

JPEG is not a type of record organization but is the most significant standard for image compression. This organization is helpful when storage space is at a premium. It uses a lossy compression plan, and its images are not interlaced. The strength of the JPEG file format is its ability to compress larger image files. Due to this compression, the image data can be stored effectively and transmitted efficiently from one place to another [98]. The JPEG council has released another adaptation of its record configuration called JPEG 2000. This new version employs a wavelet-based image compression algorithm, whereas JPEG uses DCT-based image compression. JPEG 2000 has new effective features better than the regular JPEG version [99].

3.2.3 Security Threats

Within the fast increasing developments of the internet in the recent years, parallel improvements in the need to make, duplicate, transmit, and convey computerized information, particularly interactive media (images, sound, and video), has likewise expanded. The internet has changed the way business is conducted, including the ways people communicate, interact, and purchase items. The PC networks depend on the free dissemination of data. They are constructed in a way to encourage the clients to enter and be wide open to the data procedure. These realities make them defenseless against assaults from hackers. Indeed, even before the widespread acceptance of the internet, the enterprise networks were susceptible to security threats, such as hackers taking control of the file server and gaining access to confidential data [100]. As the use of the internet has now become commonplace, the networking model and the motivations of hackers have changed. Thus, creators are stressed over hackers appropriating their work in the dread that it might be utilized illicitly through the expansion of the worldwide web (internet). This has prompted a solid demand for dependable and secure copyright assurance procedures for computerized information. Therefore, networking professionals have had to develop and maintain a detailed awareness of the vulnerabilities within their networks and access them periodically [101].

In writing, the terms 'assault' and 'danger' are generally used to mean pretty much something very similar. The security attacks are sorted into passive attacks and active attacks. Passive assault attempts to learn or utilize data from the framework; however, it does not influence framework assets. An active assault tries to adjust framework assets or influence their activity. In general, hacking networks may result from unauthorized access to the network, manipulation of data, interference with network functions, or spoofing of data packets. But what do hackers look for? The answer is:

- Gaining access to the secure and confidential data of a corporation or government agency and make unauthorized use of it.
- We are checking for security bugs in newly released software.
- Accessing money being transferred electronically.
- Crawling into a network out of curiosity.
- Executing malicious scripts for installed applications on a network server for destructive purposes.

Suggestion X.800 from the Global Media Transmission Association adds secure correspondence to Proposal X.200, which is the reference model for the open frameworks interconnection. This recommendation X.800 characterizes general security-related building parts, which can be associated fittingly in the conditions for which assurance of correspondence between open frameworks is required. It develops inside the structure of the reference model, principles and imperatives to improve existing recommendations or to become new proposals with regards to OSI to permit secure correspondence and, in this manner, give a reliable way to deal with security in OSI. Likewise, a similar association considers that security services must offer:

- Authentication: assertion that the communicating entity is what it claims to be.
- Access Control: prevention of unauthorized use of wealth.
- Data Confidentiality: protection of data from an unauthorized leak.
- Data Integrity: assurance that data received is the same as the data sent.
- Non-repudiation: protection against denial of one of the parties involved in the communication from having participated in the communication (i.e., “I didn’t send that” or “I never received that”).

There are different types of visual cryptography techniques used to secure images in digital communications. However, selecting the appropriate methods should consider the trade-off between the encryption-decryption overhead, processing time, and strong security.

3.2.4 Image cryptography

Today, the web is going towards media information in which the image is the mainstay. In any case, with the consistently expanding development of sight and sound applications, security is a significant part of correspondence and volume of images, and encryption is the best approach to guarantee security. Image encryption frameworks attempt to change the first image to another image that is difficult to understand and to keep the image private between clients. It is important to explain that without an unscrambling key, nobody can get to the substance of the picture. Pictures are generally used in quite a few processes so the assurance of images from unapproved access is significant [102]. Encryption is the change of information into a mystery code usable over a general network. Cryptography empowers the sender to safely store delicate data or transmit it crosswise over shaky networks with the goal that it can't be perused by anybody aside from the proposed beneficiary. Encryption of sensitive information is essential. It is utilized to make the data incoherent if unapproved people catch the transmission. The comprehensible structure (unique information) of data is called plain text/image, and the incomprehensible structure (secured information) is called the cipher text/figure image. The way toward changing over the plain text/image into cipher text/image is called encryption, while the annoying strategy of changing cipher text/image into the relating plain text/image is called decryption.

As a rule, most encryption calculations utilize an element called a key. The security of scrambled data entirely relies upon two things: the nature of the encryption estimation and the mystery of the key. The key is used for encryption and unscrambling and requires the sender and recipient to agree on a comparative key before making any information transmissions. The key is free of the plain text/image. Therefore, the same plain text/image is encrypted to different ciphertext /images with different keys. In this manner, the two procedures are challenging without the utilization of the right key. Encryption can be solid or powerless. Encryption quality is estimated by when and what assets it would require to recuperate the plain text/image [103]. The result of powerful encryption is ciphertext/ image that is hard to disentangle without ownership of the apt translating instrument. The sender and the recipient must stay discreet since any individual who realizes the key can utilize it. It to encode the plain text/image.

Moreover, the quality of the calculation is significant. An unapproved ent is hard to translate without ownership of the proper deciphering apparatus. The sender and the collector must stay discreet because any individual who realizes the key can utilize it to scramble the plain text/image [104]. The quality of the calculation is important. An unapproved element can take scrambled ciphertext/image and try to break the encryption by deciding the key it is dependent on. It can take encrypted ciphertext/image and endeavor to break the encryption by choosing the key the ciphertext/image is dependent on. While cryptography is an investigation by checking information, tomb assessment is the investigation of exploring and breaking secure correspondence and, as such, it is the path toward recovering the cipher text/image or key, generally by using the plain text/image and learning of the algorithm. The fundamental notion behind encryption is to alter the message with the goal that only a lawful beneficiary can reproduce its substance. A discrete-regarded crypto-system can be portrayed by:

- A set of possible plain texts, P.
- A set of possible ciphertexts, C.
- A set of possible cipher keys, K.
- A set of possible encryption and decryption transformations, E and D.

There are different types of image cryptography/encryption methods.

- **Image Encryption based on chaos theory and chaotic map:** A confusion-based image encryption plot is commonly composed of two procedures (i) permutation and (ii) diffusion. The change is accomplished by scrambling every one of the pixels, in general, utilizing a 2D turbulent guide (for example, Pastry specialist map, Arnold feline guide, and so on). During dispersion, the pixel esteems are adjusted successively; the change made to a particular pixel relies on the amassed impact of all the past pixel esteems. Be that as it may, the same number of rounds of stage and dissemination or cycles ought to be taken. The general encryption speed is moderate.
- **Chaos-based random number generator:** For a truly random generator, the number of ones and zeros in the output are equal. It is conceivable to detail numerous other factual properties that depict the keystream generated by an arbitrary source. Different test suites are accessible in writing. These accurate tests are designed to assess the arbitrariness properties of a limited grouping [105]. The unruly circle generated by a non-linear framework is sporadic, intermittent, unpredictable, and has a tricky reliance on the underlying conditions. These qualities concur with the disarray and dissemination properties in cryptography. Hence, as of late, the turbulent framework has been read for security in both digital and straight forward forms [106].
- **Stream encryption scheme:** Stream encryptions depend on delivering a constant cryptographic keystream and are used to encrypt one bit or byte at

once. Stream ciphers have relatively low memory requirements. Various image encryption schemes under this category have been proposed in the last decade [107].

- **Block encryption scheme:** Block encryption is an encryption scheme in which the plain text is broken up into blocks of fixed length and encrypted one block at a time. Block cipher of fixed length and blended one square on the double. Blocks cipher can provide integrity protection and confidentiality. Chaotic block ciphers transform blocks by directly applying the chaotic maps. Various image encryption schemes under this category have been offered in the last decade [108].

3.3 Proposed methodology

This section presents the novel framework of energy-efficient and secure digital image cooperative image transmission system.

3.3.1 System design

The system model designed for one-way cooperative image transmission over Rayleigh fading channels is shown in Figure 3.1. The nodes S and D represent the transmitter and receiver, respectively. The node S transmits an image to the node D through Rayleigh fading channel and the node D sends the ACK message to the S through the DF-based cooperative communication algorithms. The ACK message is transmitted by node D to S for the confirmation of successful image information received over the Rayleigh fading channel as per the standards of wireless communication technologies such as IEEE 802.11.

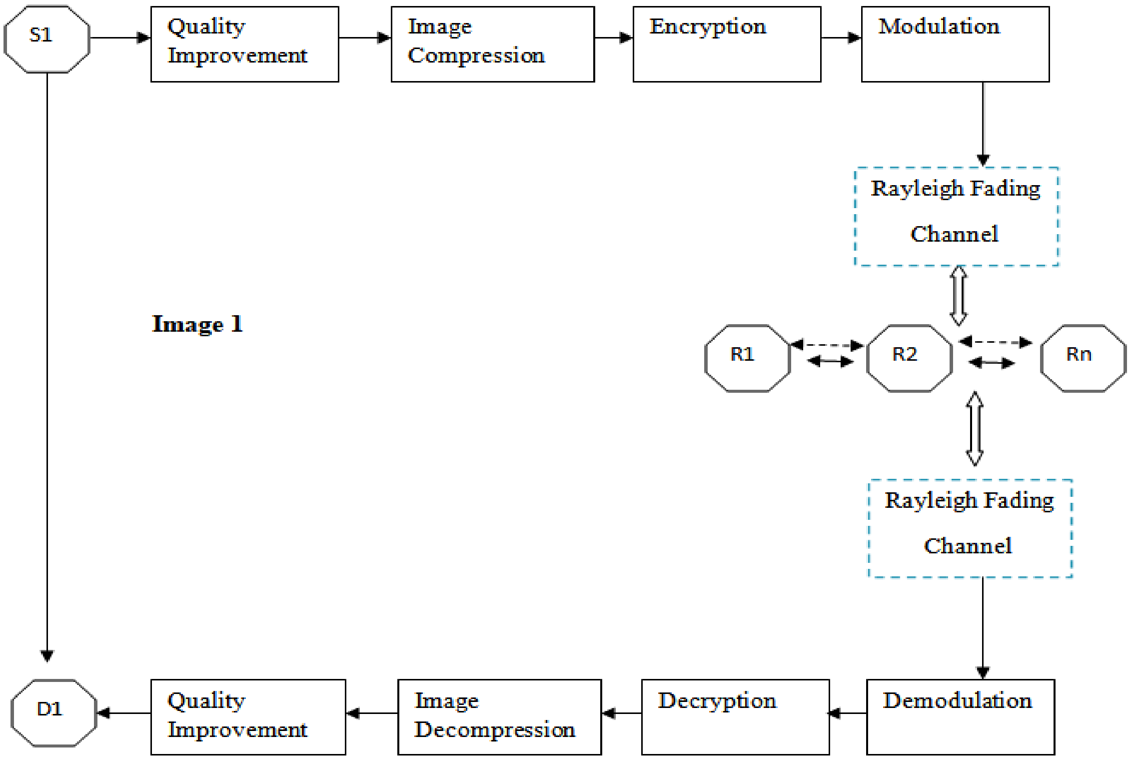

Figure 3.1 Proposed system model with a Rayleigh fading channel

Let R is the set of all relay nodes:

$$R = \{R1, R2, \dots Rn\}. \quad (3.1)$$

The input image is transmitted in different blocks through the cooperative relay nodes. In cooperative image transmission, every relay node plays two roles such as relaying role (*RR*) and monitoring role (*MR*). Relay node performs the process of image blocks transmission. Every relay node should have two parameters mentioned in Equations 3.2 and 3.3:

$$RR = \left\{R_i \mid R_j, M_j, d_{ij}\right\}, \quad (3.2)$$

where R_i is the *ith* relay node, R_j is the jth relay node. M_j is the number of total transmitters furthermore, receiver nodes associated with the ith relay node and d_{ij} is the distance among ith and jth relay node and

$$MR = \left\{M_j \mid R_i, d_{ij}\right\}, \quad i \neq j. \quad (3.3)$$

Where M_j is the jth MR node, R_i is the ith relay node connected to the jth MR node, $d_{i,j}$ is the distance between the ith MR node and the jth RR node.

The role of MR is to detect and transmit the current blocks to the nearest relaying node. Relay node then detects the received data, applies the DF method and then transmits towards the next intermediate or intended destination node. The correlation among the relay node helps to efficiently deliver the multimedia data over the wireless channel towards the intended receiver. The cooperative communication among relay nodes decodes and forwards the current image data towards the next relay node selected through correlations among all available relay nodes. Novel algorithms for image compression are implemented based on JPEG2000 and ECC-based cryptography and contribute to the functionality in the next sub-sections.

3.3.2 Image compression / decompression

In this contribution, mainly, there are two reasons for the superior performance of JPEG 2000: the embedded block coding and wavelet transform with the use of the optimal truncation (EBCOT). Thus the JPEG 2000 provides a completely novel way of interacting with image compression in an efficient and scalable manner. As the sensor nodes have limited battery capabilities, the reduction of transmitted data will lead to a network lifetime enhancement. The adaptive JPEG 2000 image compression technique using the wavelet image transform is designed as shown in Figure 3.2 (at the transmitter side).

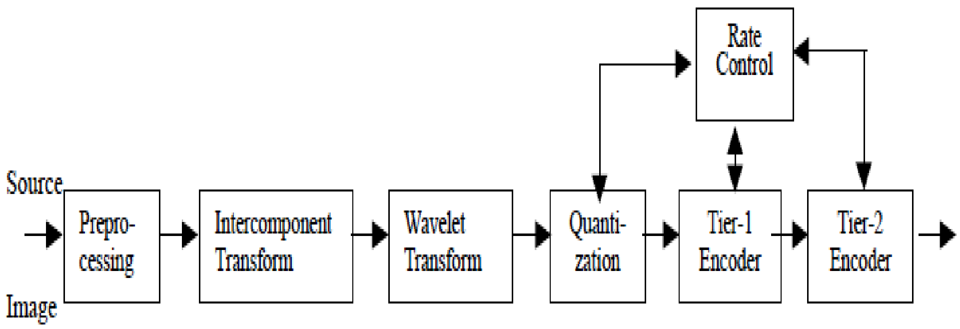

Figure 3.2 Structure of adaptive JPEG2000 compression

Figure 3.2 results into the compressed image, which is fed to the ECC-based encryption before the modulation and transmission over the remote channel. At the got end, after the demodulation and decryption, the decompression step is performed.

- **Pre-processing:** Inside the primary development, the encoder changes the test information to an excellent clear range with the objective that it is roughly engaged around zero. In case the test data is set apart, by then acknowledge they are locked in at zero.
- **Inter-component transform**: JPEG 2000, contemplates a between-segment part to be connected with the image after it has been level-moved. This change empowers the elaborate topic to relate the particular segments for multisegment images. Such transform occurrence changes over the RGB data to Cyber Data.
- **Wavelet transform:** It is a widely used technique in the image-processing domain. In DWT, each square is distinguished to be separated into the wavelet sub-packs over the various levels. The compression method JPEG 2000 exploited the lifting-based DWT. The wavelet transform is an essential task in order to generate the resolution-scalable bitstreams as well as the spatial correlation decomposition. The vector of transformed coefficient is the outcome of the wavelet transform.
- **Quantization:** The process of quantization is mainly used in lossy compression. In every sub-band, the wavelet coefficients are scalar quantized. The constant values are defined, and a dynamic range of sub-band values are used to join the step size of quantization. The quantization step is used to minimize the precision of the sub-band coefficients; thus, fewer bits are required to encode the changed coefficients.
- **Tier-1 coder:** The code blocks are delivered from every sub-band. The code squares are freely entropy-coded. The JPEG 2000 method uses the EBCOT entropy coding system, which comprises two levels. The coefficient bit context modeling, as well as the bit-plane data arithmetic coding, is executed over the block samples which then produce the embedded block bitstreams in the main working of a tier-1 coder.
- **Tier-2 coder:** In the Tier-2 coder, the compression data is used in each quality layer called the packetization procedure. Such a process of data ordering is essential in creating the SNR and resolution scalable compressed bitstream.

- **Rate control:** The rate control phase used to manage the quantizer step sizes in order to achieve the target bit-rate constraints in lossy compression. Each block bitstream is truncated to different sizes to render the best rate-contortion picture.

3.3.3 Encryption/Decryption

After the image is compressed, the compressed data is more vulnerable to different wireless channel threats. In this chapter, the security issues are examined for compressed data by using the modified ECC-based cryptography method. The key problem of the conventional ECC method is the complicated and time-consuming task of scalar multiplication which may consume the extra energy of sensor nodes, so energy consumption is optimized by elaborating the steps of ECC-based encryption and decryption in the proposed ECC-based model.

- **Key Generation**: Inside the key generation process, you have to discretionarily pick an immense whole number d, and search the $T = dG$. Where G and T are the elliptic curve points, and G is a scalar. The prevalent method for performing the scalar multiplication is the binary where d is a private key. It is fundamental to guarantee the thriving of the private key or, at the end of the day comfortable relationship to the security of the ECC encryption and decoding. There are two typical algorithms in a binary method: the left-to-right (L2R) algorithm and the right-to-left (R2L) algorithm. The L2R algorithm scans the scalar bits from the most significant bits while the R2L algorithm processes the scalar bits from the least significant bits. The L2R algorithm is widely used because it can speed up the multiplication while the R2L algorithm requires extra memory to store the partial result.
- ECC is a public key cryptosystem where every user possesses two keys: a public key and private key. The public key is used for encryption and signature verification, while a private key is used for decryption and signature generation. It is the most important step in which an algorithm is used to generate both public and private keys. Transmitter encrypts the

message data with the help of the receiver's public key and the receiver decrypts the data using its private key

- **Encryption**: The transmitter can encode the message with an open key or other keys. During the encryption procedure, the plain text should be mapped to a prime field section m, discretionarily picking a vital whole number k, processing x_1y_1 $(x_1y_1) = kG$, $(x_2y_2) = kT$ and calculating $C = m*x_2$, (x_1y_1, C) to get the encrypted data. Suppose transmitter wants to send a message m to the receiver
- **Decryption:** In the data decryption process, the receiver needs to do the calculation $(x_2y_2) = d\ (x_1y_1)$ with the private key d. The recipient can get the first plain text by computing $m = Cx_2^{-1}$.

Here, the private key d is used to ensure the basics of encryption and decryption process of the security technique. The number k has a moderate impact on data security. However, as we discussed, the complex scalar operations in k random number generation processes are proposed to minimize the computational efforts. The new methodology ECC, for the most part, relies upon the scalar k generation, which consists of steps listed ahead:

- **Scalar k generation**: In this algorithm, the "*k* random generation" method is used to generate the *k*. The *k* is generated by extending the bits from the binary string *B*. Consider that e is the bit length of base point order (*N*), assume the *h*-bit random number *B* such that $1 < h < e$. The tow- fold course of action of *k* includes two sections, the extended part (EP) and the padded part (PP). In particular, approach, get the expanded part *EP* by widening *B*. The number of bits of *k* is for the most part *w* and the expanded part is not as much as the bits of *A*, for this situation it's important to take the first couple of bits or the most recent couple of bits, or, in other words, part *PP*.
- **Calculation process**: according to the two-count methodology, the calculation process proposed right to left (R2L) (Algorithm 2) and left to right (L2R) (Algorithm 1). As a result of *PP* is left or the right

piece of the *B*, obtained the results of *BB**B* in that the computation of *B**Z*. Give the bit a chance to a number of *B* be *h*, the bit number of *k* be *e*, at that point the bit number of *PP* is $v=e\%h$. With the PP, the accompanying part delivered toward the completion of *k*. Algorithm 1 and Algorithm 2 are given as :

Algorithm 1: L2R
1. B=0; b=0 2. Computing F = W * Z with a binary method and in the calculation procedure getting O = BB * B 3. B=B+F 4. B=2^hB 5. c=c+1 6. Go back to stage 3, rehash n times, the last time end the cycle after stage 3, and don't perform stage 4 7. B=2^vB 8. B=B+O **9.** return B

Algorithm 2: R2L

1. B=0; c=0
2. Computing F = B * D with binary strategy and in the estimation procedure getting O = PP * D
3. B=B+O
4. F=2^{v}F
5. B=B+F
6. F=2^{h}F
7. c=c+1
8. Go back to stage 5, rehash n times, the last time end the cycle after stage 5, and don't perform stage 6
9. **9.** return W

- **Optimized scalar multiplication:** In the process of the proposed calculation (Algorithm 3), the mix is utilized with other scalar duplication to enhance the effectiveness of calculation. For instance, in the progression of 2 in the proposed calculation, figuring F=B*D and O=PP*D, there is a path joining with NAF (Non-Adjacent Form) calculation [106], [107]. The reinforcing with NAF computations leads the lower point expansion operation quantity during the expansion part of EP processing.

Algorithm 3: Optimization
1. N: extended random binary string generation 2. Update N, according to NAF. 3. B: Extended part generation in NAF method 4. W=0; 5. c=0 6. Compute (according to NAF method): 7. F=B*D 8. I=PP*D 9. If $N_c = 1$ then W=W+F, if $L_c = -1$, then W=W-F 10. $W=2^hW$ 11. c=c+1 12. Go to step 9, n times process repeated, at end of last iteration, the algorithm terminated at step 9. 13. $W=2^vW$ 14. W=W+O 15. return W

This proposed method significantly reduced the computational efforts in the process of encryption and decryption on compressed image and demodulated image, respectively, in the proposed one-way architecture.

3.3.4 Cooperative transmission

After the image compression and encryption process, the modulation step is performed, as demonstrated in Figure 3.1. The modulation was carried out using BPSK in order to provide better data rate Rayleigh fading distribution is assumed to be used in the links between the source *S node to relay nodes and relay nodes to the destination D node*. The modulated image blocks are transmitted cooperatively by using relay nodes over Rayleigh fading channels. As per the Equations 3.2 and 3.3, each relay node in the network plays the role of either RR or MR and does the task of cooperative image data transmission towards the receiver node. The DF technique is used at each relay; for the general case, the detection function at the relay can be given as:

$$f_{DF}(G_{BO}) = \hat{r}\,. \tag{3.4}$$

Where $\hat{r}$ denotes the decoded/detected data at the relay node. For BPSK modulation the DF detection function is provided by

$$f_{DF}(G_{BO}) = \operatorname{sgn}(G_{BO})\,. \tag{3.5}$$

Here, sgn (.) is the Signum function. The detection function is based on received data G_{BO}, identical to BPSK modulation. There is no data about the nature of the (S-D) channel.

3.4 Simulation results

This segment displays the re-enactment results and investigation of the model designed. The outcomes of PSNR, MSE, Compression Ratio (CR), Structural Similarity Index Measure (SSIM), etc. are estimated. The parameters PSNR and MSE are already described in Chapter 2. The SSIM is another image quality evaluation parameter. It is is a technique for foreseeing the apparent nature of digital TV and true-to-life pictures as different sorts of digital images and recordings. The expression for SSIM can be given as:

$$SSIM = [l(x,y)]^2 * [c(x,y)]^2 * [s(x,y)]^2\,, \tag{3.6}$$

where SSIM the structural similarity index measure, and x and y are two images. The variables l, c, and s standards for the functions of luminance, contrast and structure, respectively.

The performance metrics CR is figured as the degree of full-scale bits required for taking care of the picture before compression (BC); furthermore, complete bits are necessary for putting away the image after compression (AC).

$$\mathrm{CR} = \frac{\mathrm{BC}}{\mathrm{AC}}\,. \tag{3.7}$$

Here BC is nothing but the original image size, and AC is compressed image size. Based on various performance metrics, the proposed approach is evaluated. The digital images are taken from the publicly available research data sets such as Man, Barbara, Couple, Lena, Boat, and Cameraman. All experiments are evaluated on six images. We present the outcomes to legitimize the viability of the proposed methods.

3.4.1 Evaluations of modulation methods

In this work, it is proposed that BPSK modulation is used rather than other modulation methods such as QPSK and quadrature amplitude modulation (QAM). The BPSK method for modulation is suggested based on the experimental evaluation of BPSK with QPSK and 8-QAM modulation methods in terms of BER and throughput. Figure 3.3 and Figure 3.4 demonstrate the outcomes of BER and performance for each modulation method in the proposed one-way image transmission model, respectively.

As observed in Figure 3.3, each modulation technique is evaluated on the proposed model using both AWGN and Rayleigh fading channels separately. For both wireless channels, the BPSK modulation method shows the minimum BER performance with varying SNR. Similarly, BPSK achieved the highest throughput for image data transmission as demonstrated in Figure 3.4; the reasons for the superior performance of BPSK modulation over the QPSK and QAM in the proposed cooperative image transmission model is the simple encoding method. BPSK is the simplest method to encode data in the phase as compared to both QPSK and QAM and hence achieved the minimum BER performance with maximum throughput.

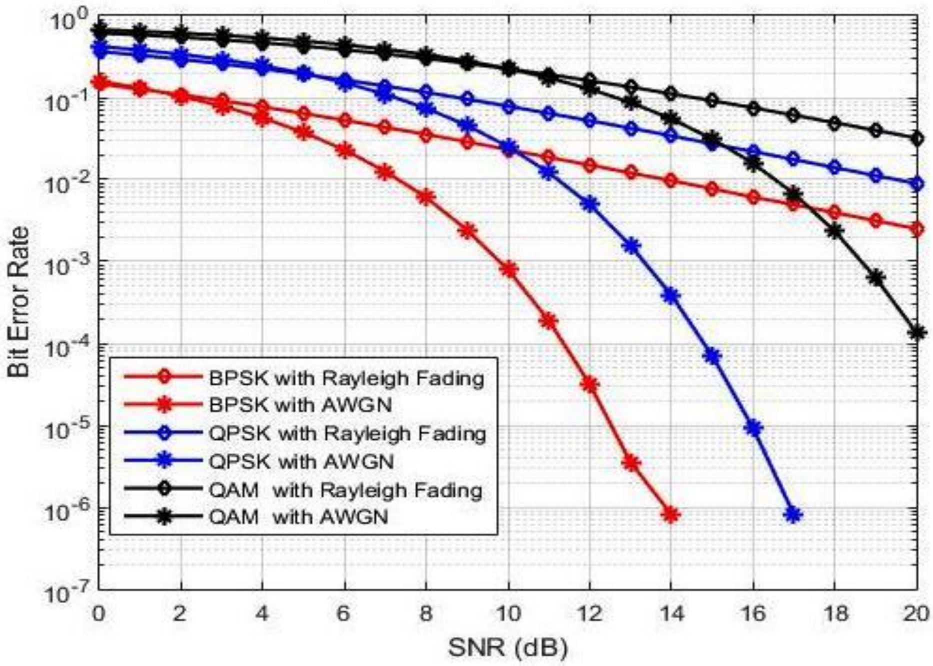

Figure 3.3 Bit error rate versus SNR

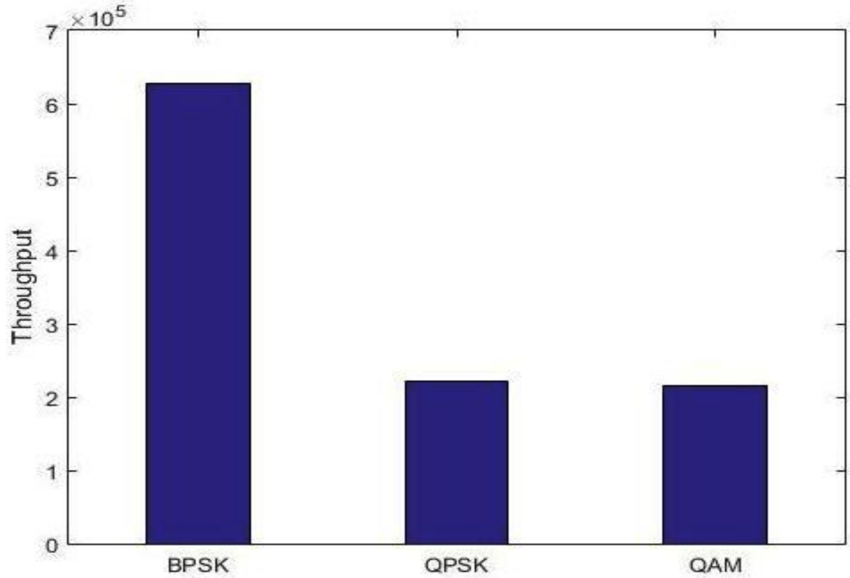

Figure 3.4 Throughput evaluation of BPSK, QPSK, QAM modulation

Note that these results demonstrated in Figure 3.3 and Figure 3.4 averaged outcomes after the evaluation of all six experimental images. Table 3.1 (Figure 3.5) shows the throughput performance of each evaluated image using all three modulation techniques.

Table 3.1 Throughput measurement using various modulations

	BPSK	QPSK	QAM
boat	703421.5	239745.1	233945.5
barbara	689726.1	252505.3	244305.6
cameraman	461654.4	158333.7	155628.2
couple	739286.1	258849.5	252846.3
lena	577743.8	203919.1	199629.2
man	784304.5	279798.9	273724.6

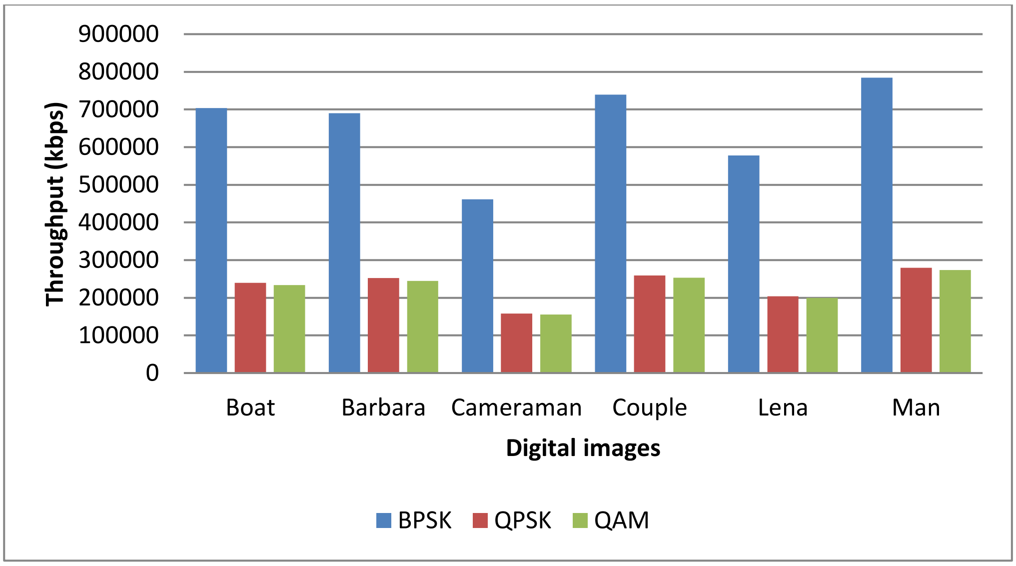

Figure 3.5 Throughput performance evaluations for BPSK, QPSK, QAM modulation

3.4.2 Evaluations of Image Compression Methods

The compression methods are evaluated in terms of many performance metrics for image mainly in two categories: image quality parameter and compression quality parameter. The pressure procedure quality is assessed utilizing the CR parameter given in expression 3.7. In this section, the CR rate evaluations are discussed. Table

3.2 (Figure 3.6) demonstrates the performance of the CR using different compression methods and proposed methods.

Table 3.2 Compression ratio evaluation

	JPEG	**2D-DWT**	**JPEG2000**	**Proposed**
Boat	1.88	4.42	11.23	13.23
Barbara	1.93	4.42	11.90	13.89
Cameraman	2.08	4.93	11.40	13.28
Couple	1.90	4.41	11.61	13.47
Lena	2.04	4.64	11.65	13.74
Man	1.87	4.46	11.43	13.59

As observed in Table 3.2, the adaptive JPEG 2000 compression method presented in this chapter shows better CR as compared to all conventional methods. The performance is compared among JPEG [104], 2D-DWT [105], and JPEG 2000 [106] methods. The JPEG method shows the worst performance for CR. The advantage of JPEG 2000 and EBCOT techniques in JPEG 2000 leads to improved CR in the proposed cooperative image transmission model. The compression technique is required to achieve the tradeoffs between the CR and image quality performance metrics especially for image compression.

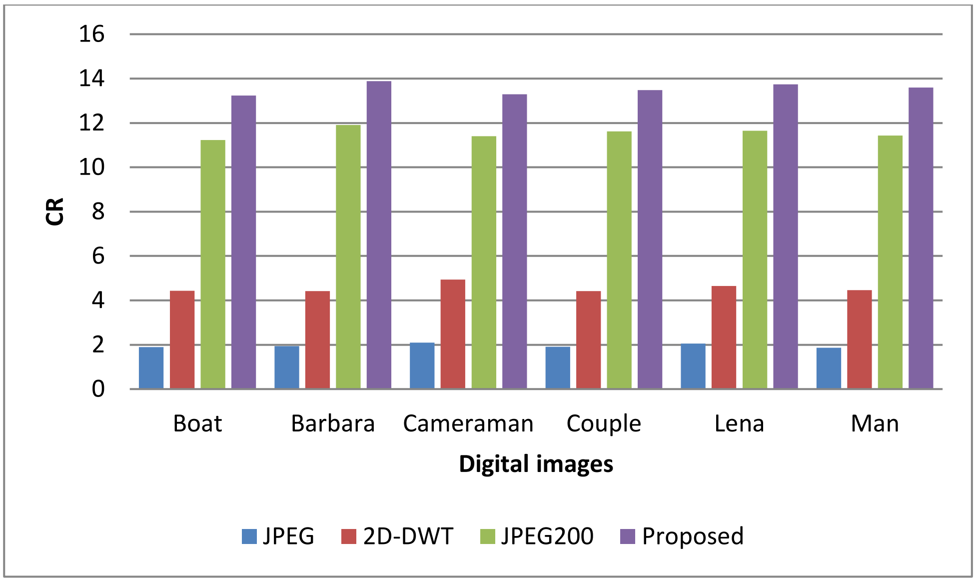

Figure 3.6 CR performance evaluations of different images

3.4.3 Evaluation of security algorithm

After the compression, security is ensured by using the modified ECC method for the proposed image transmission model. The proposed ECC method is designed to achieve computational efficiency so that the energy consumption of sensor nodes is reduced significantly. The ECC method is composed of three main tasks: key generation, encryption, and decryption. The computation efforts (time) required for key generation, encryption, and decryption are measured and compared with the existing ECC approach. Table 3.3 shows the average computation times needed for each phase. Note that the experiments were conducted on the I3 processor and 4 GB RAM configurations.

Table 3.3 Computation time analysis

	ECC (Sec.)	Modified ECC (Sec.)
Key generation	1.09	0.98
Encryption	1.98	1.47
Decryption	2.11	1.52

As observed for Table 3.3, the proposed modified ECC method achieved the computation efficiency with strong or equivalent security conditions for compressed image data. The most critical and time-consuming task of the ECC technique is scalar multiplication; therefore, modified and simplified the process of scalar number generation is used to reduce the computational efforts required. Thus, the proposed approach takes less time for all tasks of cryptography as compared to the conventional ECC technique.

3.4.4 Image quality evaluation

In this section, the image quality evaluation is done using performance metrics for the proposed model designed. The performance for picture quality is assessed for PSNR, MSE, RMSE (Root MSE), SSIM, and correlation for each tested image for a one-way DF-based cooperative image communication model. All performance metrics required two inputs: the original image (at transmitter end) and the received image (at receiver end). Table 3.4 shows all outcomes for the proposed image transmission model over the sensor network.

Table 3.4 Image quality investigation

	MSE	**RMSE**	**PSNR(dB)**	**SSIM**	**SNR(dB)**
boat.png	0.1289	0.3591	57.058	0.999873	28
barbara.png	0.1636	0.4045	56.025	0.999678	28
cameraman.png	0.1828	0.4276	55.543	0.999916	28
couple.png	0.1280	0.3579	57.089	0.999869	28
lena.png	0.0771	0.2777	59.292	0.999928	28
man.png	0.1042	0.3229	57.982	0.999866	28
Average	0.1443	0.3749	56.8	0.9998	28

All results show that the proposed model for cooperative image transmission achieved efficiency for the image quality; the quality of all tested images are not comprised using the proposed methods at each phase of the communication model. The error rate (MSE and RMSE) is very low and the quality rates (PSNR and SNR) are highest for all the images. Similarly, the SSIM and correlation results show that the received images match the original transmitted images considerably.

3.4.5 State-of-art evaluations

The proposed cooperative image transmission technique is assessed for three key performance metrics with new techniques, for example, PSNR, and energy efficiency. The performance of the proposed method is compared with methods reported for cooperative image transmission over the WSNs. These methods are proposed for cooperative image transmission in a different domain.

Table 3.5 Comparative average PSNR analysis

Algorithm	**PSNR (dB)**
Lecuire et al. [2]	31
Nasri et al. [14]	20
Yasar Abbas et al. [80]	46
Contribution 1 (Chapter 2)	51.6
Proposed Method	56.8

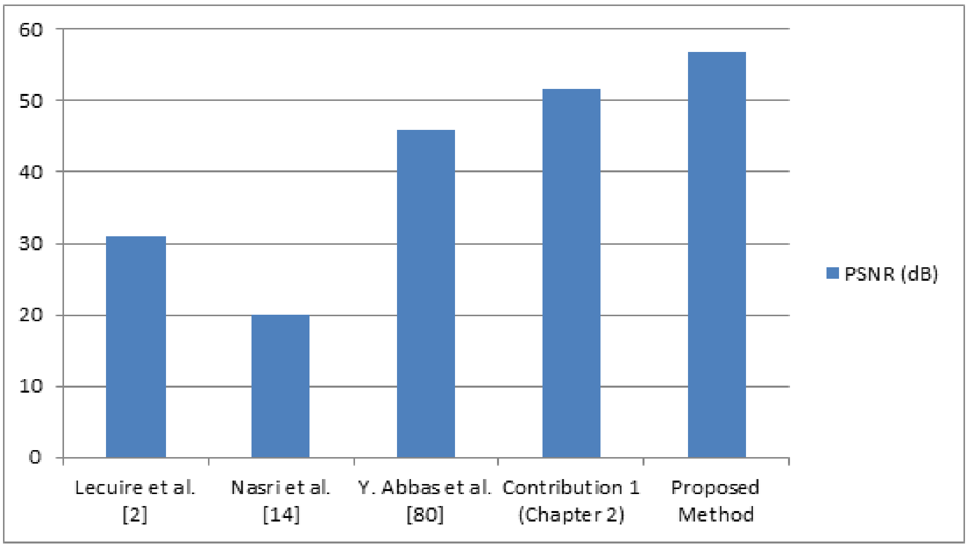

Figure 3.7 Average PSNR analyses

Table 3.5 (Figure 3.7) demonstrates the average PSNR results for each method. The simple reason for performance improvement in PSNR using the proposed model is the use of compression, encryption, and modulation technique that does not allow data loss during the cooperative transmission process. The encryption technique helps to protect any security threat on compressed data; hence the possibility of quality degradation is reduced. The outcomes of PSNR and energy efficiency claim the robustness of the proposed, one-way secure image transmission model designed.

Table 3.6 Comparative average energy consumption analysis

Algorithm	**Average consumed energy (mJ)**
Lecuire et al. [2]	1252.6
Nasri et al. [14]	1251.9
Yasar Abbas et al. [80]	411.3
Proposed Method	392.7

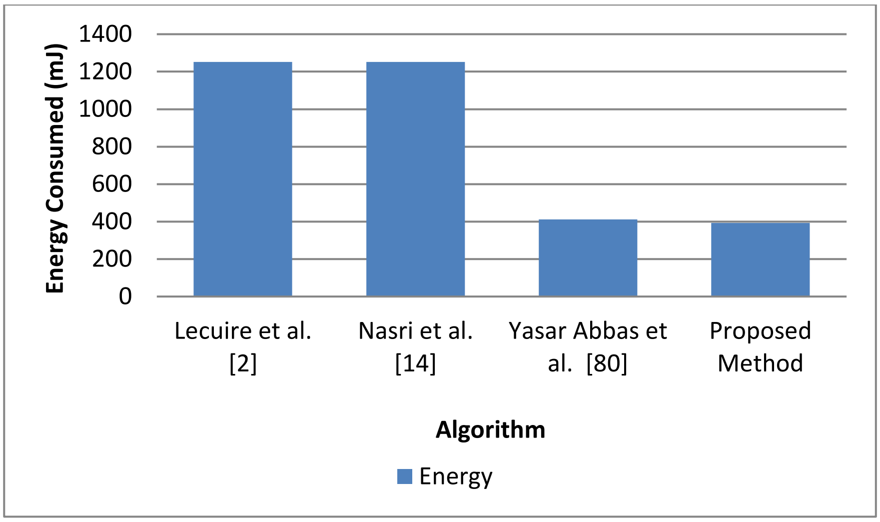

Figure 3.8 Avarage energy consumed analyses

Table 3.6 shows the average energy consumption performance for all methods. It is estimated that in all sensor nodes, beginning vitality is assigned 0.5 joules. After sensor nodes are involved in the process of image transmission, the receiving and transmitting energy is consumed by 392.7 milli-joules (mj). After the complete transmission of vitality from source to target nodes, the normal vitality utilization of all sensor nodes in the network is measured. The total number of sensor nodes deployed in the network is 20. The results show that the proposed framework achieved a reduction in energy consumption performance as compared to previous methods. The proposed compression and cryptography techniques help to reduce the number of transmissions in the proposed model; hence the performance is optimized for energy efficiency as compared to state-of-the-art methods.

3.5 Summary

In this chapter, we present and evaluate the second contribution of this thesis. The efficient one-way cooperative secure image transmission model for wireless multimedia sensor networks over Rayleigh fading channels is the main research challenge because of the limited capabilities of sensor nodes; thus a model is designed to fulfill the various challenges of WMSNs for image transmissions such as scalability, energy efficiency, security, and image quality. To enhance the performance of image quality and energy efficiency, the image compression technique with BPSK modulation is proposed. To protect the compressed image data, the lightweight ECC technique is suggested. The one-way image transmission in MIMO channel communication is another research challenge for wireless image transmission that needs to be addressed.

4

One-way Image Transmission in Multiple Input Multiple Output Systems over Rayleigh Fading Channel

4.1 Introduction

In Chapters 2 and 3, we presented the inputs on the one-way image transmission by considering the image quality, image compression, image security, and energy efficiency challenges over WMSNs/WSNs. Both modes show a significant improvement over the existing methods. However, one-way communication in multiple-input multiple-output (MIMO) is yet to be solved. One-way image transmission in a fading channel requires an image to be good with channel qualities such as data transfer capacity, vitality productivity, time utilization, and security in light of the fact that the image consumes large space in a gadget and also experiences more threats than in the one-way communication.

Another problem is the additional time taken in compression results since the secondary process of the compression followed by the acquisition consumes more time. It is noticed that in the one-way image transmission in the MIMO increase in the size of the bit rate of images added propagation time and more power consumption and bandwidth utilization. For better utilization, various compression techniques can be utilized to reduce the bit size of an image but the consumption of more time in preprocessing results in the emerging of compressive sensing (CS), which compresses the image by sensing with the nature of dimensional reduction and random projection. Any information through the channel needs not only the compression but also the security from the various cipher attackers such as Data Exfiltration, Bad Data Injection, etc. Many types of research paved the way for solving the security issues in compressive sensing by providing security. Also, while transmitting into the channel, the noise that is added should accurately estimate the receiver side so that the input image could reconstruct into their original form. Thus, for a better one-way image transmission in MIMO, this chapter designs a novel module to transmit the image with less energy consumption and more security. The key highlights of this contribution are:

- The novel system model of one-way communication in the MIMO system over a Rayleigh fading channel.
- The security method designed as per the functionality of one-way communication in MIMO.
- The study of the functionality of different modulation techniques presented.
- Performance evaluation presented.

Before presenting the one-way image transmission in the MIMO framework, in Section 4.2, the study of different MIMO modulation techniques reviewed. In Section 4.3, the proposed methodology is presented. In Section 4.4, the simulation results are discussed. In Section 4.5, the summary presented.

4.2. Modulation Techniques

For a MIMO system, modulation methods play a significant part in data transmission. There are different types of modulation techniques; the most commonly used modulation methods such as BPSK, QPSK, and QAM are discussed in this section. The constellation diagrams of 16-QAM, 32-QAM and 64-QAM, are given in Figure 4.1, 4.2. and 4.3.

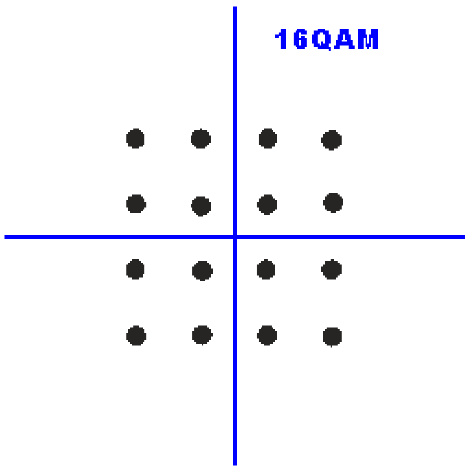

Figure 4.1 Constellation diagram of 16-QAM

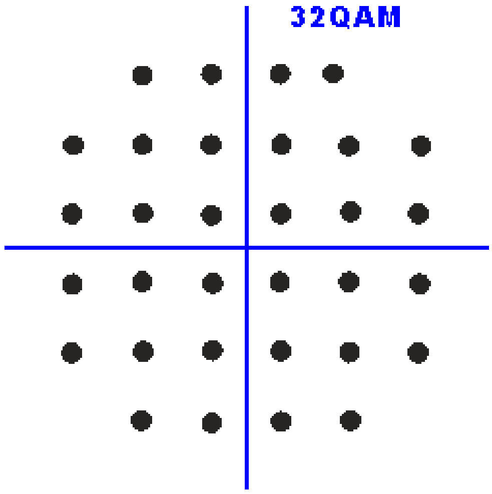

Figure 4.2 Constellation diagram of 32-QAM

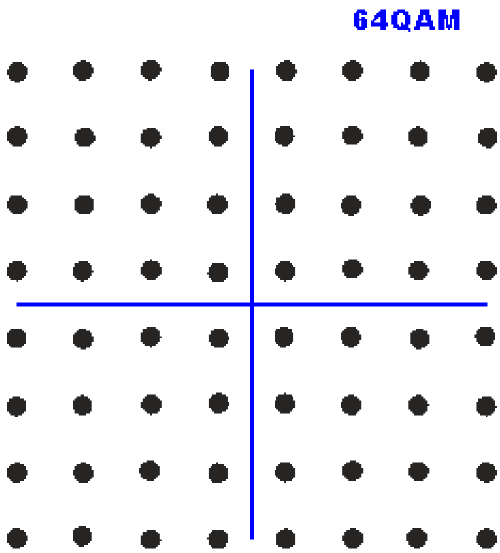

Figure 4.3 Constellation diagram of 64-QAM

The different kinds of QAM may be used when information rates past those offered by 8-PSK are required by a radio correspondences structure. This is because QAM accomplishes a more prominent separation between contiguous focuses on the I-Q plane by scattering the concentrates even more equally. Furthermore, along these lines, the focuses on the group of points on the constellation are more distinct and data errors are reduced. While it is possible to transmit more bits per symbol if the energy of the constellation is to remain the same, the points on the constellation must be closer together and the transmission becomes more susceptible to noise. This results in a higher bit error rate than for the lower order QAM variants, and

Along these lines, there is an amicability between gaining higher information rates and keeping up a satisfactory piece error rate for any radio trades system.

4.3. Methodology

4.3.1. System model

The One-way image transmission in the MIMO system arises the problem of consuming more energy due to large bandwidth utilization by a massive number of bits and undergoes various processes like acquisition, compression, transformation, which needs extra computational time; this way reduces the speed of the processing time. Hence, to overcome as a combined source for acquisition, compression, and transformation, the concept of compressive sensing is utilized by their nature of dimensional reduction and random projection that sensed on its own and reduced the bandwidth utilization. As for CS, the initial selection of random variables for image acquisition is an essential factor because the improper selection of random variables in CS makes it complicated to retrieve the image due to the addition of noise. Owing to the nature of the dimensional reduction and random projection, the technique does not hold the security parameters. If the security is provided after the compression process, it takes more time. Hence, to solve the issues mentioned, the research has interestingly proposed a one-way image transmission in the MIMO module. This module performs with less bandwidth and selecting the random variable in the spatial domain as a regularized form using least-squares models and uncovers a considerable sum about the conduct of the estimators. Figure 4.4 shows the proposed one-way image transmission in the MIMO model.

Along with this, confusion and diffusion of a chaos property in a tinkering bell are utilized as a mapping condition which has the specialty of being understood by only those familiar with the language of the fairies so the image bits cannot be understood by cipher attackers, thus providing high security to the image bits. To transmit these bits without any distortion of signals, there is a need to have a modulation scheme which is carried out for transmission in the MIMO channel that is allowed to access the full-duplex channel to allow it to communicate in both directions. While transmitting through the fading channel and AWGN gets added, so it could be filtered properly in the reconstruction phase to recover the original encoded bits.

Accordingly, in this proposed module, the usage of mid-rate bit coding of modulation can recover the original bits with their clock recovery property by knowing the original bits state and added noise state. Therefore, the intelligent module will reduce the need for new filtering techniques that consume additional time. The module provides better energy efficiency and secured one-way image transmissions by their process of quantization with security and the transmission scheme. The whole scheme of the proposed one-way image transmission is described ahead.

In Figure 4.4, User 1 and User 2 connect in one-way image transmission in the MIMO module transmission system. At the transmitter end, the user transmits the image by constructing the random variable as a compressed form from the original image and then, using the chaotic property of the tinkering bell, the variables in the image get encrypted. Then for transmission via the channel, the image gets encoded with the BPSK-based modulation coding, through which noise in the channel can be estimated for one-way transmission, a full-duplex system in the MIMO channel. In the reconstruction phase, the noise influences get minimized by the clock recovery property, then decoding begins followed by the decryption and the reconstruction process is done so the receiver gets the original image. The mathematical explanation for the proposed module is given ahead in the following subsection.

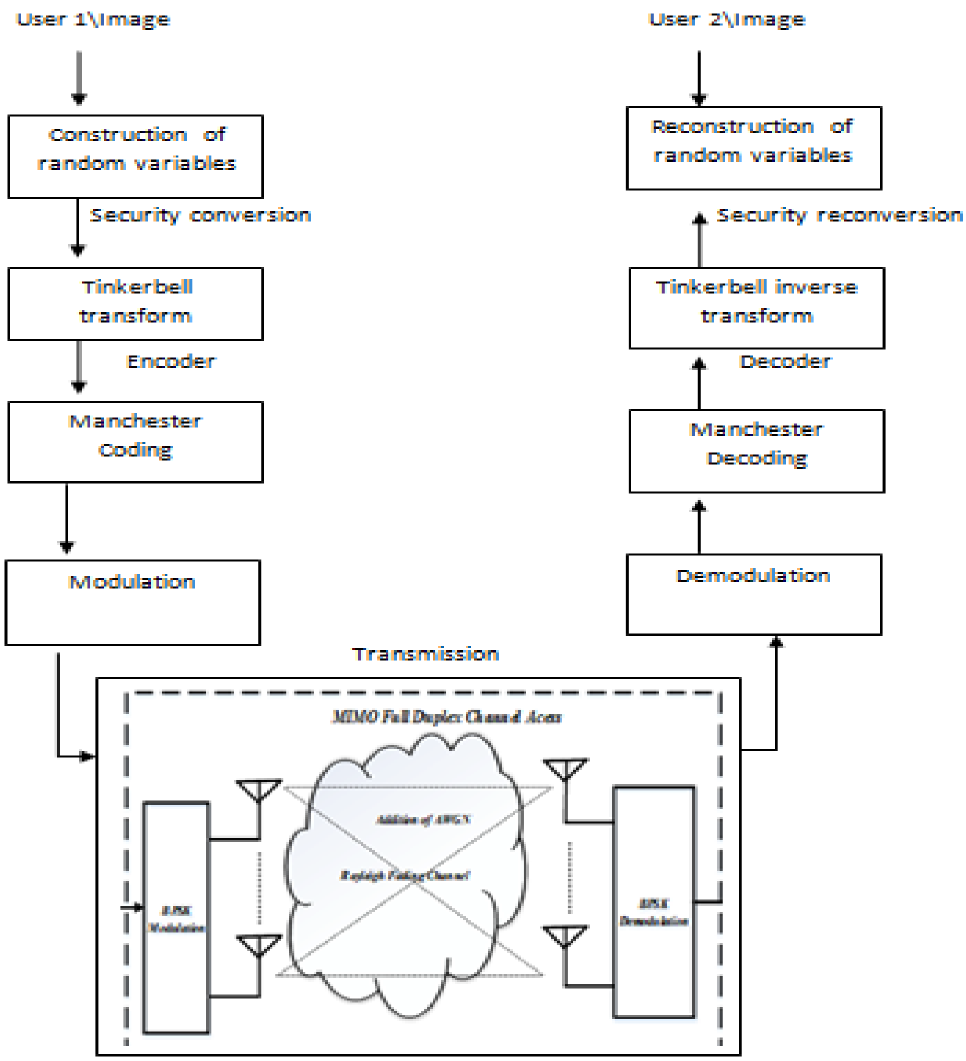

Figure 4.4 One-way image transmission in MIMO

The diagrammatic representation for the transmission channel, at the receiver end, the image signals get demodulated by BPSK, and using the clock recovery property of modulation code, they are decoded to their original form. To recover the original image, the reconstruction phase is carried out that can be explained in the following section.

4.3.2. CS Image Security

Let us consider the image I_m which has to be transmitted by the users is given by Equation 4.1 as

$$I_m = \begin{bmatrix} P_{1,1} & P_{1,2} \dots & P_{1,j} \\ P_{2,1} & P_{2,2} \dots & P_{2,j} \\ P_{i,1} & P_{i,2} \dots & P_{i,j} \end{bmatrix}. \quad (4.1)$$

Here i, j = 1, 2, ..., n. If the image is transmitted by user 1 to user 2, owing to the high number of bits in I_m, the bandwidth utilization in the channel gets increases; thus, the way the requirement of energy gets increased and affects the entire transmission system. So to get energy-efficient and less bandwidth utilization, the need for compressing the image I_m is required. Now, the proposed module introduced a security matrix in the CS as an in-built process and is termed a compressed security matrix.

To generate the compressed security matrix, '**C**', for the image I_m in Equation 4.2, the input image and the random measurement matrix with the security matrix are multiplied together. This can be described mathematically and is given ahead as

$$C = \alpha\overline{\omega}I_m. \quad (4.2)$$

Where, $\overline{\omega} \in I_m^{i\times j}$ or $P_{ij}^{i\times j.}$ is the random measurement matrix, $C \in I_m^{i\times j\cdot}$ or $P_{ij}^{i\times j.\cdot}$ is the compressed security measurement vector of length i and $\alpha \in I_m^{i\times j}$ is the security matrix of area i×j

Here, the quantity of estimations taken is a lot lesser than the length of the information picture, i.e., i<j. The size of the estimation lattice and the number of estimations are concerning the sparsity of the data signal. The systems for building the C matrix using the proposed module are given ahead.

Step 1: Sensing input image for transmission

The input image I_m is sensed for the transmission, which can be represented by the pixel value P_{ij}. The property of the pixel P_{ij} is given by

$$\mathbf{P_{ij}} = \begin{bmatrix} a_1 & a_2 \dots & a_m \\ b_1 & b_2 \dots & b_m \\ z_1 & z_2 \dots & z_m \end{bmatrix}. \quad (4.3)$$

Here a, b,.., z represents the features of the image I_m.

Step 2: Construction of random measurement

In the construction phase of the proposed module, it is essential to select the random measurement because the improper selection of the random measure leads to imperfect retrieval of the image. So, the construction of random measurement $\overline{\boldsymbol{\omega}_\mathbf{I}}$ is carried out to improve the expectation precision and interpretability of relapse models by changing the model fitting procedure. Let us consider the features from the image pixel $P_i = [a_i, b_i, c_i, \dots, z_i]$ and construct the random measurable for ϖi given by

$$\overline{\boldsymbol{\omega}_\mathbf{I}} = \frac{1}{N}\sum_{i=1}^{N} f(P_i, P_{ij}, \tau, \cup). \tag{4.4}$$

Where $P_i= (P_i)^T$ are the predictor features variables, x_i are the responses, and τ, υ are the recovering parameters for prediction accuracy and interpretability. In Equation 4.4, the module chooses a sub-set of the covariates to accomplish both of these objectives by driving the aggregate of the absolute estimation of the relapse coefficients to be a lower sum than a fixed worth, which stimulates specific coefficients to be set to zero, successfully picking a less complicated model by excluding coefficients.

By selecting these coefficients with prediction accuracy and interpreting the parameters, the random variables can be easily identified and reconstructed in the final stage. To protect these variables from the various cipher attacks, the need for encryption arises and can be explained in the following process.

Step 3: Construction of a security matrix

The security matrix having a 2-D discrete-time dynamical system obtained from the equation 4.5 in is subject to the current chaotic values a_i followed by the next chaotic values b_i and its control parameters p, q, r, s, which helps to confuse and diffuses the attackers [109-113], are given by the equations

$$a_{i+1} = a_i^2 - b_i^2 + pa_i + qb_i. \tag{4.5}$$

$$b_{i+1} = 2a_ib_i + ra_i + sb_i. \tag{4.6}$$

The initial values considered are a_0, b_o and parameters are p= 0.9, q= -0.6013, r= 2.0, s=0.50. By their confusion and diffusion property with the features, the pixel values in the image get encrypted and make every value in the image pixel get protected from the attackers. The chaotic values in Equations 4.5 and 4.6 of the Tinkerbell map make the pixel in the encrypted form and provide confusing information about the data, thereby making it more complicated for the attackers [115], to produce the compressed secured form of an image the following mathematical evaluation is carried out.

Step 4: Creation of Compressed secured image

By the designed scenarios mentioned earlier, the input from the image, the matrix formed by the random measurable in Equation 4.4, and the chaotic values obtained in Equations 4.5 and 4.6 get multiplied and form the compressed secured matrix output given by Equation 4.7 as

$$\mathbf{c_i} = \begin{bmatrix} a_i \\ b_i \end{bmatrix} \left[\frac{1}{N} \sum_{i=1}^{N} f\left(p_{ij,}, xi, \tau, \nu\right) \right] \begin{bmatrix} P_{11} \\ P_{12} \\ P_{1j} \end{bmatrix}. \tag{4.7}$$

By the above equation 4.7, the obtained matrix is in the compressed form of:

$$\mathbf{c_i} = \begin{bmatrix} c_{11} \\ c_{12} \\ c_{1n} \end{bmatrix}. \tag{4.8}$$

Thus as stated, the image is compressed in the; Further, it's a single matrix; hence the number of bits gets reduced which in turn produces energy-efficient transmission with less utilization of bandwidth. Also, by the transformation of the pixel values into the chaotic values, all the pixels get encrypted, thus protecting the image data from the attackers. The pseudo-code for the construction for compressed security is given in Figure 4.6.

Figure 4.5 explains that in the first stage, the image which has to be transmitted is selected by representing all the values in the form of a pixel representation. Then, the random measurement is chosen as a unit row or column matrix and gets utilized. Finally, for security, chaotic values are generated, and by the multiplicative factor, the final compressed secured matrix formed. Now the compressed secured output has to be transmitted into the MIMO channel so that User 2 can receive the image of User 1.

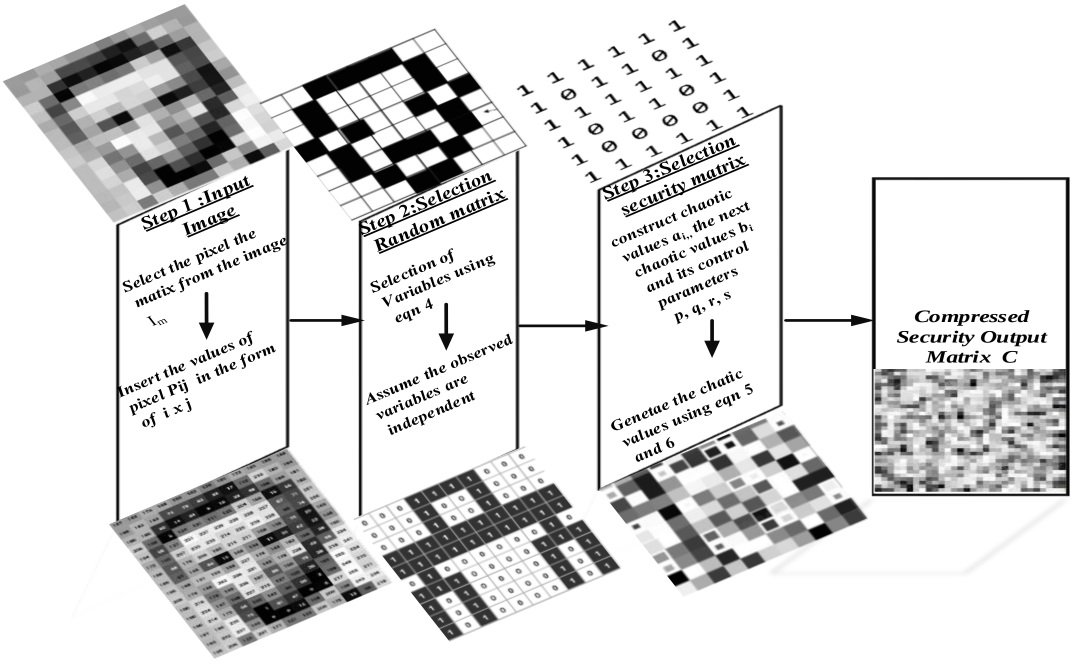

Figure 4.5 A Pseudocode for compressed security matrix

4.3.3. Image transmission using MIMO

To improve framework limit and dependability, the module utilizes the MIMO technique. With the improvement of reception apparatus, MIMO, and obstruction dropping methods, it is conceivable to understand the synchronous transmission on a similar band simultaneously. What's more, the shrouded terminal issue and clog issue brought about MAC booking, and the vast postponement issue in the multi-hope remote system can be solved in MIMO. The parameters considered for channel transmission are shown in Table 4.1.

Table 4.1 One-way image transmission in MIMO

Terms	**Method Considered**
Transmission/receiving scheme	MIMO
Channel access	Full duplexing
Modulation Scheme	BPSK
Coding Scheme	Modulation Coding
Fading Channel	Rayleigh fading Channel
Noise Considered	Additive White Gaussian Noise (AWGN)

Modulation encoding practices the inversion in the middle of each bit interval for both synchronization and bit representation. By using a single transition for a double purpose, modulation encoding attains the same level of synchronization as a return to zero with two levels of amplitude only. Like other existing coding methods, modulation code trails an algorithm for data encoding. This algorithm performs as follows: The representation of data is that of line transitions. A logic 0 is indicated by a transition from HIGH to LOW, and a logic 1 is as vice versa.

The representation of Modulation encoder is given by

$$K(t)=c_i \oplus CL. \tag{4.9}$$

By obtaining the number of bits, the BPSK modulation done for the full-duplex MIMO channel which is provided by

$$\emptyset(t) = K(t)\sqrt{\frac{2}{b_s}\cos(2\pi q_c t)}, \tag{4.10}$$

Where q_c frequency term, b_s is the number of bits every second

For the transmission, the framework includes two nodes; every node has two radio wires that can transmit and get information. As far as one node goes, the MIMO transmitting signal preparing the module transforms the digital signal into two branches. This system enables the node to transmit and get packets at the same time and can improve the system's unwavering quality and information rate through extra coding and space with assorted variety procedures. After modulating the signal, they are transmitted through the Rayleigh fading channel with the AWGN noise included. By using the MIMO channel with full-duplex access, the reliability and data rate of the system are improved. BPSK modulation coding is done for modulation.

4.3.4. Image reconstruction phase

After transmitting the modulated image signal into the MIMO channel with full-duplex access, the received signal from the channel with the addition of AWGN into the Rayleigh fading channel is given by the expression

$$\theta(t) = \emptyset(t) + e, \tag{4.11}$$

Utilizing Equation (4.11), the signal gets demodulated by the BPSK that is given by

$$\widehat{K(t)} = \frac{\widehat{\emptyset(t)}}{\sqrt{\frac{2}{b_s}\cos(2\pi q_c t)}}. \tag{4.12}$$

After demodulating the signals in the reconstruction phase, the signal which is encoded with the modulation coding gets decoded by the clock recovery property of the modulation which is given by the Equation (4.9) as

$$\hat{c} = CL \oplus \widehat{K(t)} \;. \tag{4.13}$$

Now the original modulated signal gets decoded. Then to retrieve the original image, the following systematic procedures are utilized by separating each matrix to obtain the original image. The selection of a security matrix can be decrypted by the inverse function of the chaotic values of the tinkering bell. By knowing the initial chaotic values, the decryption of the matrix is done by the values which have been set initially and are given by

$$\hat{\alpha} = \begin{bmatrix} a_i \\ b_i \end{bmatrix}^{-1}. \tag{4.14}$$

Then the random matrix, which was obtained by the condition of the regression principle, can be predicted by

$$\bar{\omega} = \min_{tv} \left[\frac{1}{N} \sum_{i=1}^{N} f(P_{ij}, C_{ij}, \tau, \nu)\right]. \tag{4.15}$$

Thus by predicting the random matrix by the regression principle, decrypting the chaotic values, and the proper estimation of noise, the original image obtained in the reconstruction phase is given by

$$I_n = \frac{\hat{c_1}}{\hat{\omega}\hat{\alpha}}. \tag{4.16}$$

Where I_n is the original image reconstructed by the proposed Module. The pseudo-code for the reconstruction phase of the proposed module is shown in Figure 4.6

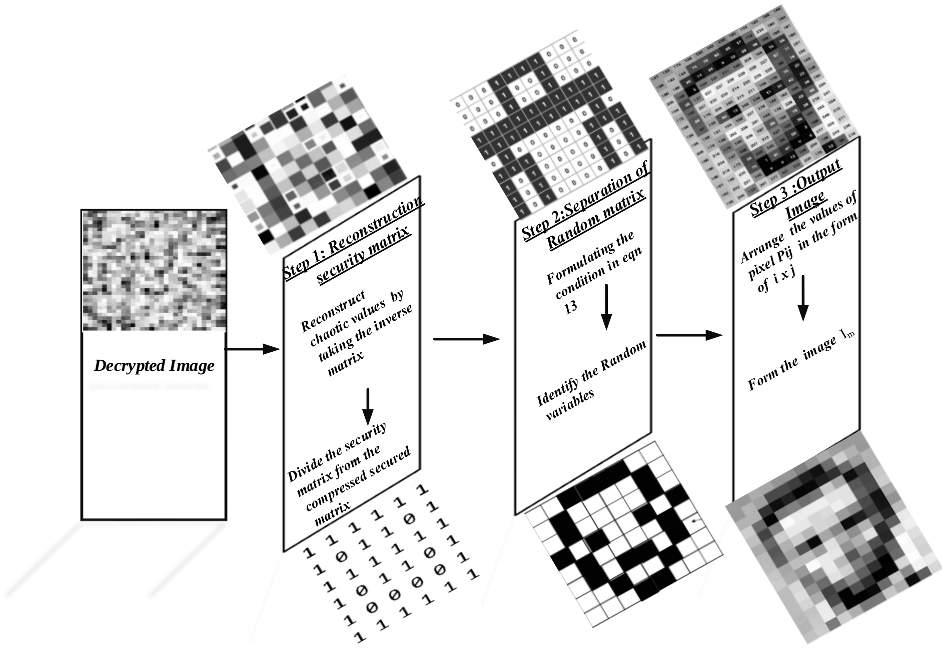

Figure 4.6 Reconstruction of the original image

Figure 4.6 explains that to decrypt the image, the reconstruction of the compressed secured matrix is carried out, at which the inverse calculation for the chaotic values of the tinkering bell is calculated initially and then using the prediction of the regression principle, the random matrix is reconstructed accurately. This principle helps to get the original image as an output. The overall algorithm for the proposed is given ahead in Algorithm 1.

Algorithm 1: proposed Module

Input: Image: I_m

Output: Image: I_n

Stages: Construction, Transmission, Reconstruction

Stages 1 : Construction of compressed security matrix

$C = \alpha \overline{\omega} I_m$. by details

Let $I_m = \{P_1 \ldots\ldots P_n\}$ I1....In Image pixels

If, Random matrix $\overline{\omega} \in {I_m}^{i \times j}$ or ${P_{ij}}^{i \times j}$, For $\overline{\omega}_i = \frac{1}{N} \sum_{i=1}^{N} f\left(P_i, P_{ij}, \tau, v\right)$

Then, if Security Function $\alpha \in {I_m}^{i \times j}$

1. For $a_{i+1} = a_i^2 - b_i^2 + pa_i + qb_i$ and $b_{i+1} = 2a_i b_i + ra_i + sb_i$.

Construct the compressed secured matrix: $c_i = \begin{bmatrix} a_i \\ b_i \end{bmatrix} \left[\frac{1}{N} \sum_{i=1}^{N} f\left(P_{ij}, x_i, \tau, v\right)\right] \begin{bmatrix} p_{11} \\ p_{12} \\ P_{1j} \end{bmatrix}$

End.

Stages 2 : Transmission through MIMO channel code

2. $K(t) = c_i \oplus CL$

Modulate,

$$\emptyset(t) = K(t) \sqrt{\frac{2}{b_s} \cos(2\pi q_c t)}$$

Stages 3 : Reconstruction of original image

Assume,

$\theta(t) = \emptyset(t) + e$

3. $\widehat{K}(t) = \frac{\widehat{\emptyset}(t)}{\sqrt{\frac{2}{b_s}} \cos(2\pi q_c t)}$

4. $\widehat{c_i} = CL \oplus \widehat{K}(t)$

End,

Reconstruct the matrix,

decrypt by the inverse function of the chaotic values of tinkering bell

If, $\widehat{\alpha} = \begin{bmatrix} \alpha_i \\ b_i \end{bmatrix}^{-1}$

Get decode the random matrix, which was obtained

5. $\overline{\omega} = \underset{t\,v}{\mathrm{Min}} = \frac{1}{N}\sum_{i=1}^{N} f\left(P_{ij}, C_{ij}, \tau, v\right)$ Where $\|v\| < t$

The output original image obtained in the reconstruction

6. $\mathbf{I_n} = \frac{\widehat{C_\iota}}{\widehat{\overline{\omega}}\widehat{\alpha}}$

End

By the overall design of the proposed, the large numbers of image bits get compressed by the compressed secured matrix, which helps in less bandwidth utilization meanwhile producing the energy-efficient transmission and by the secured property in the matrix makes it complex for the attackers to hack the image. The intelligent selection of random variables by the prediction and integrality property of the regression principle reconstructs the image accurately in the reconstruction phase. Transmission of signals in the MIMO channel by the full-duplex channel access and the utilization of the BPSK modulation scheme with Manchester coding helps to recover the signals after the transmission through the Rayleigh fading channel even with the addition of AWGN. Doing as a combined module, the additional computation time taken for secondary processes gets neglected thereby increasing the speed of the transmission. The image gets more compatible with the channel bandwidth and transmits securely with low computation time by the compressed security matrix when the module is employed for the one-way image transmission in MIMO.

4.4. Simulation Results

To exhibit the effectiveness of the proposed module regarding energy efficiency, time consumption, and security, the simulation is carried out in MATLAB using the images of the DIP book. This section presents those results.

4.4.1. Visual outcomes

Step 1: Input image

To validate the process, six input images such as Cameraman, Barbara, Man, Couple, Lena, and the Ship are considered for the transmission shown in Figure 4.8.

Figure 4.7 Input images

Step 2: Selection of random matrix

For the selection of the random variables, regression principles are carried out for the input images and a random matrix carried out by the random variable regression principles for the six input images.

Step 3: Construction of compressed security matrix

By the utilization of the regression techniques and the chaotic values of the tinkering bell, the construction for the security matrix is carried out.

Step 4: Transmission of compressed secured image

The process is executed after considering specific parameters, which are tabulated ahead in Table 4.2.

Table 4.2 Processing parameter image transmission

Parameter	**Description**
Channel type	Downlink/uplink
Number of the transmitting station	2
Number of receiving station	2
Number of users	2
Number of bits transmitted	1024 bits/packets
Bit rate	1 kb/sec
Modulation scheme	BPSK (Manchester coding)
Noise Considered	Additive white Gaussian noise (AWGN)

The proposed executes with 2x2 MU-MIMO channels with 1024 bits in single packet size. This process is carried out by the BPSK modulation scheme evaluating with users at a time. When the above signals are transmitted through the fading channel with the AWGN noise is added along with the signal. After the addition of those noises, the signals are altered. The addition of AWGN in the Rayleigh channel changes the signals in the channel. Hence to recover that, the reconstruction process is carried out that can be explained by the following stages.

Step 5: Reconstruction of compressed security

After the addition of AWGN into the channel, the estimation of the BER is carried out to recover the original signal encoded by the Manchester coding. For that, the clock recovery of Manchester is utilized to decode the original signal. Then using the predictive and integrality function of the regression principle, the random variables which were selected in the initial stage are recovered. It has been proved that using the proposed model, the input image which has been transmitted by the user through the one-way communication channel gets compressed, secured, and occupies less energy and finally reconstructs the output image which is like the input image. Then to assess the presentation after-effects of the proposed, seven parameters are evaluated that are presented in the next section.

4.4.2. Performance Evaluation

This segment shows the proposed approach for performance evaluation in different parameters such as PSNR, SNR, BER, time, etc. Some of the formulas of performance metrics have already been presented in previous chapters; other performance metrics were measured as well and are presented ahead.

Let I(x,y) is the original image, I'(x,y) is the approximated version, and M, N are the dimensions of the images. The difference between I(x, y) and I'(x,y) would provide the error.

Root Mean Squared Error (RMSE): Root mean square was dictated by taking the root of MSE.

$$RMSE = \sqrt{MSE} \tag{4.17}$$

Signal to Noise ratio (SNR): SNR is defined as the ratio of average signal value to the standard deviation of the background values. SNR can be used as a measure of sensitivity. The value becomes normalized when the SNR is divided by its dimensions:

$$SNR = \mu_{xy} / \sigma_{xy}. \tag{4.18}$$

Where μ is the average among the image pixels x, y and σ is the standard deviation of the pixels of the foundation.

Table 4.3 Performance evaluation for the proposed module in terms of PSNR, and processing time and BER

Images	PSNR(dB)	Processing Time (s)	BER
Couple	41.7653	1.4056949	0.003052
Barbara	41.7718	1.4202456	0.003089
Cameraman	33.7585	1.5236545	0.003022
Lena	41.94	1.4527804	0.003032
Man	41.14	1.5079328.	0.003084
Ship	42.38	1.5636474	0.003062

From the above results, analyzing the parameters such as PSNR, BER, SSIM, time, and the proposed shows the effective values for the six images. The average results of PSNR are 40.46 whereas the value is BER which is due to the effective design of the high-quality image received. By the usage of the compressed security matrix and the full-duplex access for the transmission, with a fast transmission speed of 1.47 sec.

The structure similarity index measurement is computed as:

$$SSIM = [l(x,y)]^2 * [c(x,y)]^2 * [s(x,y)]^2 \quad (4.19)$$

Where x is the image input and y is the image output, The variables I,c, and s standards for the functions of similarity local path luminance and local path contrast and local path structure respectively.

Table 4.4 Performance of SSIM

Images	**SSIM**
Barbara	0.560887
Cameraman	0.371988
Couple	0.558823
Ship	0.57498
Lena	0.434309
Man	0.531887

The Table 4.4 (Figure 4.8) describes the structure similarity index measurement (SSIM) obtained for the six input images, the maximal SSIM was seen for the Couple image and the least for Cameraman.

Figure 4.8 Structure similarity index measurement for the six input images

4.4.3. State-of-art evaluations

The proposed methodology of comparison with the other existing methodology of Lecuire, Nasri, Singh, hybrid watermarking, Yasar Abbas, Contribution1, and

Contribution2, in the table Table 4.5 the proposed methodology is compared with the other six current methodologies in terms of their PSNR.

Table 4.5 Comparison of proposed methods with the existing techniques based on PSNR values

Algorithm	**PSNR (dB)**
Lecuire et al. [2]	31
Nasri et al. [14]	20
Hybrid watermarking [108]	28.3
Singh et.al [108]	30.81
Yasar Abbas et al. [80]	46
Contribution. 1 (Chapter 2)	51.6
Contribution. 2 (chapter 3)	56.8
Proposed method	41.6

Table 4.5 describes the comparison to some of the proposed methodologies, our model possessed the PSNR value of 41.6 shown averages; thus that the proposed system works well compared to others. Communication time is the total time consumed for the communication process while transmitting the user data from one place to another.

Table 4.6 Comparison of communication time with the existing techniques

Methods	**Time Consumption (ms).**
JPEG2000	366
DCT	471
SPIHT	331
JPEG	544
Proposed	275

Table 4.6 shows the communication time performance. The Table displays the proposed methodology compared with the other existing methodology in terms of their communication time. It seems that the current methodology of JPEG 2000, DCT, SPIHT, JPEG shows 366,473, 331, and 544 milliseconds respectively. Comparing the proposed methodology, it possesses the value of 275 milliseconds and showing that due to the proper modulation and transmission, the module becomes effective and possesses low communication time

Table 4.7 Comparison of energy consumption with the existing techniques

Methods	**Energy Consumption (mJ)**	**% Energy saving**
Lucire et al. [2]	1252.6	87.47
Nasri et al. [14]	1251.9	87.48
Yasar Abbas et al. [80]	411.3	95.88
Contribution 2 (chapter3)	392.7	96.03
Proposed	383.6	97.64

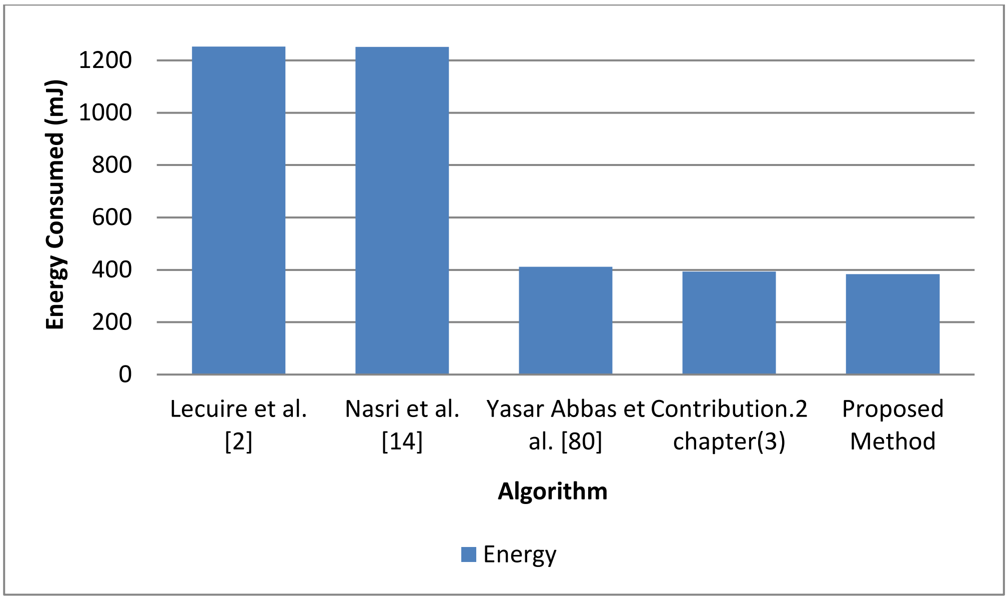

Figure 4.9 Average energy consumed analyses

From Table 4.7(Figure 4.9), the proposed methodology is contrasted with the other existing methodology regarding their energy utilization and energy saving. It seems that the current methodology has high energy consumption and low energy saving. The proposed methodology consumes energy of 383.6 mJ and saves 97.64 % energy, showing the efficient energy utilization by the proposed module.

4.5. Summary

This chapter presents the final contribution of this research work in which a secure and energy-efficient one-way image transmission in the MIMO model has been designed. A discussion of the complete system model and the contributions for image compression, CS, security algorithm, the MIMO parameters, and modulation techniques are given in this section. The comparative results are extensively disclosed with similar methods at the end.

5
Result and Discussions

5.1 Conclusion

In this thesis work, we presented the different models of cooperative image transmission over the WSNs. We noticed that recent cooperative communication suffered from various research challenges such as energy efficiency, image quality, and security. Thus the key objective was to propose the single direction and one-way image transmission correspondence in MIMO modules utilizing the properties of MIMO. For this research, the cooperative communication model consisted of the source node (which captures the image, i.e., transmitter), a relay node (intermediate node), and destination node (receiver node). The contributions are based on the various techniques used for firmness and safekeeping.

Chapter 2 represented the first contribution in which the efficient one-way image transmission technique using the image pre-processing and image compression method was designed. Image quality improvement efficiency is essential in multimedia applications and wireless communications. We proposed a novel technique based on adaptive and dynamic noise removal and quality improvement for both, before and after compression. The compression method was designed based on the 2D-DWT technique. The cooperative transmission was performed by the relaying technique called DF. The simulation results of this contribution are analyzed using the DIP book images with state-of-the-art methods.

Chapter 3 presented the second contribution in which we address the challenges of energy efficiency and security, which are missing in the first contribution. The novel, scalable, and efficient image compression and decompression method by using techniques under the transform domain are used. To address the security challenge, the modified elliptic curve cryptography (ECC) based lightweight cryptography technique is designed. The one-way model using such compression and security method was designed and evaluated with existing methods.

Finally, Chapter 4 introduced the final contribution of this research in which the one-way secure image transmission in the MIMO model was designed. The extensive results using the different quality parameters and efficiency parameters were presented for this contribution. From the simulation results of all the contributions, the proposed methods overcame the challenges of existing techniques related to energy efficiency, image quality, and security.

5.2 Future work

For future work, we suggest various directions such as

- Investigating the different watermarking methods in proposed models rather than using the cryptography techniques to minimize the computation overheads.
- Introducing parallel computing frameworks to reduce computation overheads.
- Applying the energy efficiency algorithms on relay nodes before selecting them for image data transmission to save energy consumption.
- Applying the proposed models to real-time communication systems to validate the simulation results.

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Publications from the thesis

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Papers

1. B. Al-Hayani, H. Ilhan, "Efficient cooperative image transmission in one-way multi-hop sensor network," International Journal of Electrical Engineering Education, vol. 56, no. 2, pp. 1-19, 2018. (DOI: 10.1177/0020720918816009)

2. B. Al-Hayani, H. Ilhan, "Image transmission over decode and forward based cooperative wireless multimedia sensor networks for Rayleigh fading channels in medical internet of things (MIoT) for remote health-care and health communication monitoring," Journal of Medical Imaging And Health Informatics, vol. 10, pp. 160-168, 2020. (DOI: 10.1166/jmihi.2020.2691).

3. B. Al-Hayani, H. Ilhan, "Visual Sensor Intelligent Module Based Image Transmission in Industrial Manufacturing for Monitoring and Manipulation problems," Journal of Intelligent Manufacturing, Under Review, JIMS-D-19-00764R1.