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Visual sensor intelligent module based image transmission in industrial manufacturing for monitoring and manipulation problems

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Abstract

Due to technology advancement, smart visual sensing required in terms of data transfer capacity, energy-efficiency, security, and computational-efficiency. The high-quality image transmission in visual sensor networks (VSNs) consumes more space, energy, transmission delay which may experience the various security threats. Image compression is a key phase of visual sensing systems that needs to be effective. This motivates us to propose a fast and efficient intelligent image transmission module to achieve the energy-efficiency, minimum delay, and bandwidth utilization. Compressive sensing (CS) introduced to speedily compressed the image to reduces the consumption of energy, time minimization, and efficient bandwidth utilization. However, CS cannot achieve security against the different kinds of threats. Several methods introduced since the last decade to address the security challenges in the CS domain, but efficiency is a key requirement considering the intelligent manufacturing of VSNs. Furthermore, the random variables selected for the CS having the problem of recovering the image quality due to the accumulation of noise. Thus concerning the above challenges, this paper introduced a novel one-way image transmission module in multiple input multiple output that provides secure and energy-efficient with the CS model. The secured transmission in the CS domain proposed using the security matrix which is called a compressed secured matrix and perfect reconstruction with the random matrix measurement in the CS. Experimental results outwards that the intelligent module provides energy-efficient, secured transmission with low computational time as well as a reduced bit error rate.

Keywords Intelligent module smart system · Data transmission · Data compression intelligent sensor · Visual sensing automation · Coding · Regression

Introduction

In visual sensor networks (VSNs), when images with more information required transmitted over a long distance, there is a need for efficient utilization of bandwidth (Mahesh et al. 2016), lesser power consumption, less time is taken, and a minimal amount of space. This leads to performing the compression of the image by reducing the redundant data (Salvatore 1997). The various image enhancement approaches proposed to improve the quality of the image, but such methods suffer from visual deterioration problems (Kwak and Park 2014; Lee et al. 2009). Visual sensors automation is used to monitor and track objects combined approaches based on multiple wireless sensor systems for time condition monitoring of electric machines (Ilhan et al. 2015). The sensors overview introducing the available technologies for monitoring with a focus on radio frequency-based technologies of transmission (Zhou and Shi 2008) carried in vehicles or dislocation of vehicles in a networked area without regular infrastructure. Visual sensing automation used vehicular networking with sensors. The emergence of 'sensor on wheels' in-car brings the additional features to driver-assisted systems integrated in present-day vehicle designs (Manapragada and Kluesing 2014). Welding is a thermal processing method; sensing using infra-red (IR) thermal image and camera are most extensively employed for monitoring and control of the welding process (Chandrasekhar et al. 2015). Based on advanced technologies

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such as data communication techniques, sensor networks, and radiofrequency identification, it is then presented in Liu et al. (2017). Figure 1 shows the illustration of the image transmission process through the wireless channel.

During image acquisition, the received signal needs to be reformatted to obtain the original image transmitted, but this signal would also include redundant information (Karakus et al. 2013). Hence, a precise compression technique required to remove such unnecessary data from input signals. Signals are represented as a sparse or compressible form across various domains (Zhang et al. 2012). The CS reconstruction algorithms can securely reconstruct the original signal to the original form with minimum data loss (Rauhut 2010). The process of CS demonstrated in Fig. 2 in the wireless channel.

The foremost requirement of CS for precise reconstruction is that measurements must prefer randomly through the correct selection of the measurement matrix. The random matrices in the CS domain are extracted using either Gaussian or Bernoulli distribution or partial Fourier matrices (Rauhut 2010). These random matrices are incoherent with any other basis and obey the restricted isometric property (RIP) condition of perfect recovery (Tropp and Gilbert 2007). If Gaussian distribution belongs to an orthonormal basis, then the matrix will also have Gaussian distribution and hence will able to recover the exact solution with high probability (Tian et al. 2002). The CS has evaluated along with random measurement matrices, but the problem with random matrices it that they cannot be stored and reproduced at the received end (Otazo et al. 2015). Therefore these matrices required to transmit along with the visual signal, which is not practical for signal processing applications. Hence the research interest shifted towards the design of deterministic and structured measurement matrices that can be used as CS measurement matrices. The common examples of these matrices are circulant, Toeplitz, structured random matrices, etc. (Haupt et al. 2010). The advantages of structured random matrices are faster acquisition, minor storage requirement, reproducibility, and reduced transmission overhead, while the drawback is the requirement of providing security of the image while transmitting through the communication medium (Ponuma and Amutha 2017).

The existing CS reconstruction algorithms attempted to find out the sparse estimation of the original input signal, from compressive measurements, on some suitable basis or frame or dictionary (Paredes et al. 2007). A lot of research conducted on this perspective of CS to come up with better-performing algorithms. The research driving factors in this area is the ability to recover from a minimum number of measurements, noise robustness, speed, complexity, performance guarantees, etc. (Liu et al. 2017). Due to noise additions in the wireless medium, the CS reconstruction phase regrets in estimating the random measurement metrics in CS. Wireless channel is random and having multiple reflectors in the environment that leads in fading. Multiple reflections generate multiple paths for a visual signal transmission from the transmitter to the receiver termed as multipath propagation (Watteyne et al. 2010). Multipath propagation results a high fluctuations in the phase and amplitude of the signal. Hence modulating the signal is an essential need while transmitting into the channel. Interleaving techniques are essential to combat the effect of bursty errors due to fading, interference and multipath propagation in wireless communication (Kohno et al. 1995). By using linear minimum mean square error (LMMSE) equalization at the receiver, the system analyzed by using helical and chaotic

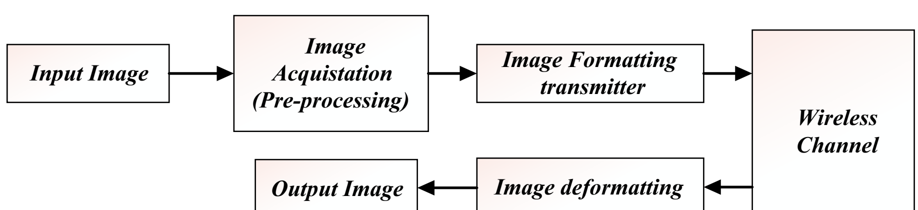

Fig. 1 Image transmission through wireless sensor networks (WSN)

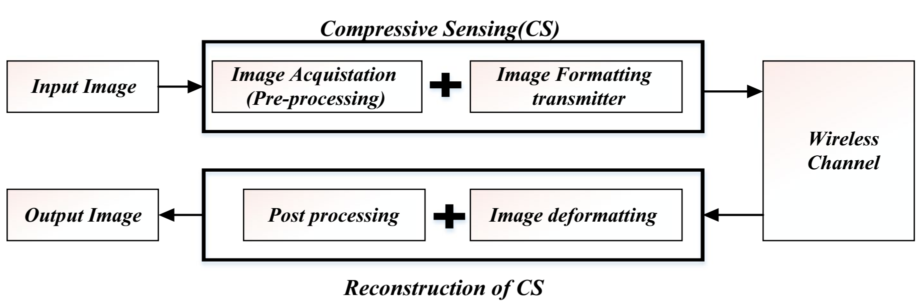

Fig. 2 Image transmission using the CS technique

interleaving (El-Bakary et al. 2013). Based on observations of peak signal to noise ratio (PSNR) and root mean square error (RMSE), interleaving techniques concluded that chaotic interleaving performs better than helical interleaving. The 16-HQAM (hierarchical quadrature amplitude modulation) for image transmission improves the bandwidth efficiency with the absence of dc-component from transmitted signal and median filter to reduce noises at noisy additive white Gaussian noise (AWGN) channel. HQAM is the advanced version of QAM at the same data transmission rate with improved protection of the specific region in an image from the added noise in the channel. The region of interest (ROI) is mapped at the most significant bit and background mapped to least significant bi positions, which improved image quality even at lower signal to noise ratio.

From the above discussion, it is clear that in the one-way image transmission model, the increased bit rate size of images leads to propagation time and energy consumption with bandwidth utilization. Thus for better utilization of bandwidth various compression techniques proposed to reduce the bit size of an image, but consumption of more time in preprocessing leads emerging of compressive sensing that compresses the image by sensing with the nature of dimensional reduction and random projection. Any information that transmits through the channel need 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 a way to solve the security issues in CS by providing security as a secondary process, which takes more time thus none will show a result as an inbuilt process in CS. Besides, while transmitting into the channel, the noise, which added, should properly estimate on the receiver side so that the input image could reconstruct into their original form. Thus, for better one-way image transmission, the paper designs an intelligent module to transmit the image with less energy consumption and more security over the wireless channel. "Related works" section presents a brief review of related works. "Intelligent system module" section presents the proposed methodology and design. "Results and discussion" section presents the experimental results and their analysis. Finally, "Conclusion" section presents the conclusion of this research work.

Related works

Recently some works attempted to address the problems of efficient one-way cooperative image transmission over the wireless sensor networks (Ahmad et al. 2017; Song et al. 2019; Hassen 2008; Al-Hayani and Ilhan 2020a, b; Singh et al. 2016; Ur Rehman et al. 2016). The method for separable data hiding in encrypted images utilizing CS and discrete Fourier transform proposed in Ahmad et al. (2017). As indicated by that strategy, CS utilized just to pack and encode the parts containing the mystery message in the wake of hiding the secret message. The measurement number for CS reconstruction diminishes monotonically with the reduction of overhead rate. To keep the image not extraordinarily augmented, the overhead rate must be a little esteem. In this way, with the reduction of the number for CS reconstruction, it is not conceivable to correct inserted data and recover a unique image. Another technique of an orthogonal matrix using the Gram Schmidt calculation proposed in Song et al. (2019). During the time spent block-wise temporary change, the calculated guide was utilized trailed by the dissemination procedure. The method explains in performs encryption and decryption utilizing the symmetric key, i.e. a similar key (mystery key) utilized at the encryption and decryption side. Image encrypted with a mystery key can unscramble just with a similar mystery key. The idea of spatiotemporal confusion can additionally enhance the security effectiveness of the plan. Two dynamic strategies for image transmission over binary channels with added substance bursty commotion displayed by the limited memory Polya(contagion) channel proposed in Hassen (2008). The strategies, which in light of channel-optimized scalar quantization (COSQ) of the wavelet change coefficients, misuse channel memory to offer better execution over various more perplexing frameworks intended for the completely interleaved channel. The block fading channels proposed in Al-Hayani and Ilhan (2020b) with relay assisted distributed spatial diversity and exposed by joint-source–channel coding schemes. A joint source–channel rate allocation scheme that maximizes the flat Rayleigh fading channel using inputs of BPSK and Gaussian was explored. The system brings up the optimization in the PSNR ratio and the BER performance was better when the number of subcarriers get increased.

In the above works, we noticed the various limitations of image transmission in wireless sensor networks. The core idea about Ahmad et al. (2017) and Song et al. (2019) is to provide the security in the CS for the image transmission using encryption and decryption. They explain the way of protecting the images through the symmetric key scheme and the permutation process but their works fail to concentrate the reconstruction of original data with less number of measurable. Furthermore, the channels are identified and somewhat rectified by the works of the Hassen (2008) and Al-Hayani and Ilhan (2020b). However, it is noticed that there is still missing security provision as an inbuilt process in CS and the proper estimation of noise in the random measurable of the reconstruction phase. Therefore there is a motive for the research to rectify the issues in the one-way image transmission by providing the inbuilt security and the proper estimation in the reconstruction phase. This paper addressed by proposing the novel one-way image transmission model.

Recently we introduced system model designed for one-way cooperative secure image transmission in which the *source* (S) node transmits an image to the destination node (*D*) through Rayleigh fading channel and the node *D* sends the *ACK* message to the *S* through the DF-based cooperative communication algorithms in Singh et al. (2016). The transmitter (T) plays out the image quality improvement first and then the image is compressed using the 2D-DWT technique. Finally, the tweak and IFFT tasks are performed on a compressed image packets. The image packets forwarded to relay nodes over AWGN remote channel. Once the packets received at the receiver end, then reverse operations performed to recover the original image. The results are compared with the existing methods and evaluated. Another state-of-art recent technique proposed in Al-Hayani and IIhan (2020a) for the visual sensor networks, but problems remain similar discussed above. In Ur Rehman et al. (2016), our work introduced for one-way image transmission proposed with compression and image encryption algorithms proposed. From the recent methods, it is noticed that an efficient security mechanism yet to achieve in CS and the accurate estimation of noise in the random measurable of the reconstruction phase. Some other works presented recently in Lecuire et al. (2008), Nasri et al. (2010), Krishna et al. (2018), Stoyanov (2016), Alshibani and Ibrahim (2015), Yuan (2011) and Pappachan and Baby (2015). In this paper, we further extended our work by rectifying the problems of one-way image transmission in MIMO by providing the inbuilt security and the proper estimation in the reconstruction phase.

Intelligent system module

One-way image transmission system leads to the problem of excessive energy consumption because of large bandwidth utilization. The huge number of bits and various processes like acquisition, compression, transformation, etc. takes extra computational time and large bandwidth utilization. To overcome such problems in this paper we proposed the intelligent system model of one-way image transmission. At the transmitter end, processes like acquisition, compression, and transformation in CS utilized by their nature of dimensional reduction and random projection, which sensed itself and reduced the bandwidth utilization. Concerning CS, the initial selection of random variables for image acquisition is an essential factor because the improper selection of random variables in CS makes complicate to retrieve the image due to the addition of noise and also owing to the nature of the dimensional reduction and random projection, the technique does not hold the security parameters whereas if the security provided after the compression process, it takes more time. Hence, to extract the above well said problems intelligently, the research has interestingly proposed a one-way image transmission using the MIMO module.

Additionally, the confusion and diffusion of a chaos property in a tinkering bell utilized as a mapping condition in quantization which has the specialty of understanding only to those familiar with the language of the fairies so the image bits cannot be understood by cipher attackers thereby provides high security to the image bits. Then to transmit these bits without any distortion of signals, there is a need to have the modulation scheme which is carried out for the transmission in the MIMO channel that is allowed to access in the full-duplex channel, which makes to communicate in both directions. While transmitting through the channel, the additive white Gaussian noise (AWGN) gets added, so it could be appropriately filtered in the reconstruction phase to recover the original encoded bits. Accordingly the methodology regarding high life battery, energy utilization, and energy saving. It seems that the existing methodology possesses high energy consumption and low energy saving. Comparing the proposed methodology it low consumes the energy and high save the energy-efficient and energy utilization by the proposed module. We use, in this proposed module, the usage of mid-rate bit coding of Manchester 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, which consumes additional time, here. By the overall creation, the module provides better energy efficiency and secured one-way image transmissions by their process of quantization with security and the transmission scheme. The methodology regarding their energy utilization and energy saving. It seems that the current methods possess high energy consumption and low energy saving. By using the compression technique like compressive sensing (CS), best from others like JPEG2000, JPEG, DWT, and utilizing the cryptography event algorithm like 2D Tinkerbell best from ECC (DES) (AES) (RSA) algorithms respectively are some of the conventional cryptographic algorithms. But digital images possess high redundancy and these are not suitable for image encryption. Chaos-based encryption is one of the new effective methods of cryptography for images. And the MIMO model is best in energy saving from cooperative communication because more relays are there are consume energy, according to their event techniques will high life battery. Figure 3 shows the proposed system architecture consists of transmitter and receiver modules for visual data transmission.

As observed in Fig. 3, the user 1 acts the image transmitter and user 2 acts the image receiver in the proposed one-way image transmission using MIMO. At the transmitter end, the user transmits the image by constructing the random variable as a compressed form from the original image, then image data encrypted using the chaotic

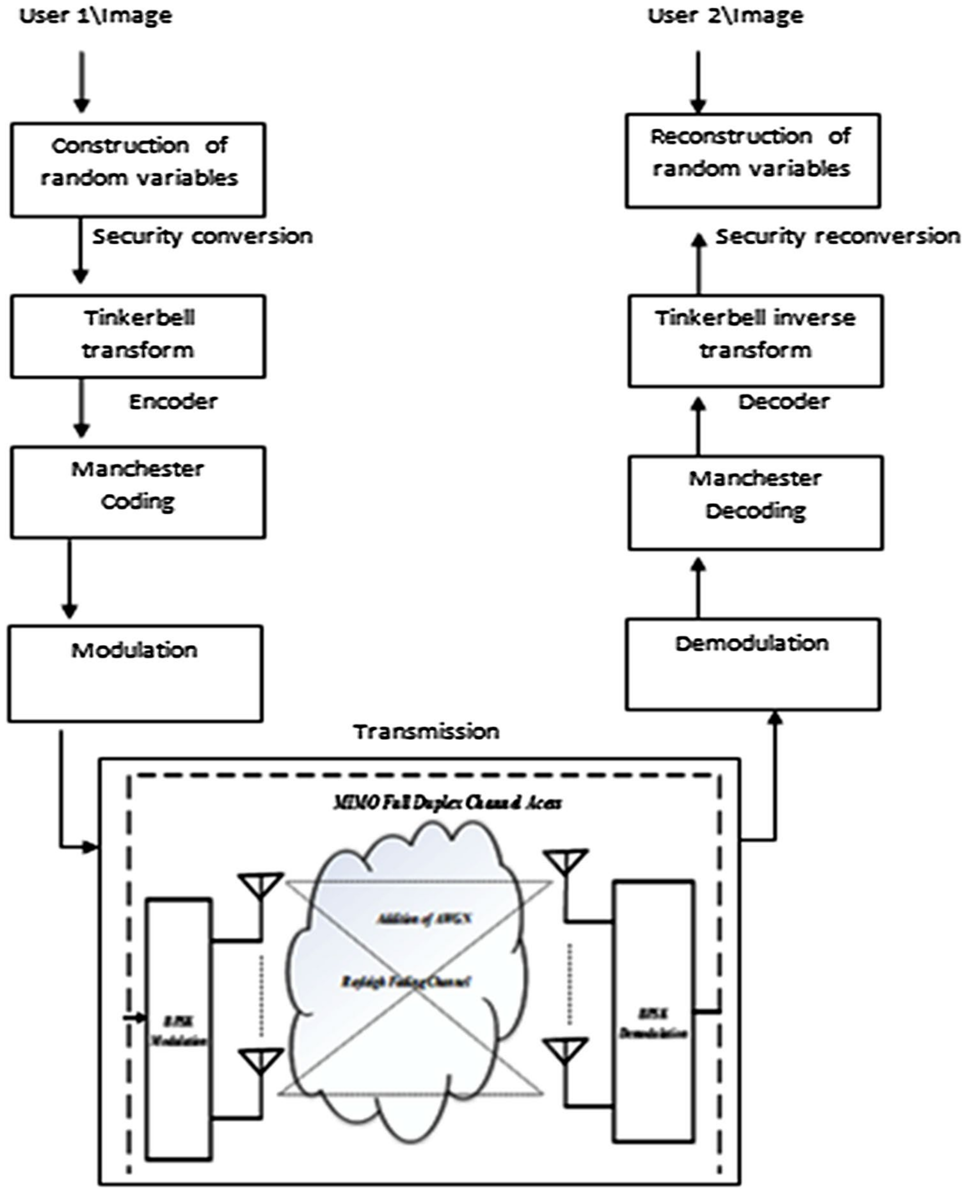

Fig. 3 A one-way image transmission through a MIMO system over the Rayleigh fading channel

property of the tinkering bell. To transmit encrypted data via the wireless channel, the image encoded with the BPSK-based modulation coding, through which noise in the channel can be estimated for the image transmission, a full-duplex system in the MIMO channel. In the reconstruction phase, the noise impacts minimized by the clock recovery property, then decoding begins followed by the decryption and the reconstruction process performed at the receiver to receive the original image. The mathematical explanation for the proposed module is given ahead in the following section. The diagrammatic representation for the transmission channel, at the receiver end, the image signals demodulated by BPSK and using the clock recovery property of modulation code, they are decoded to their original form. In the receiving phase, the noise influences minimized by the clock recovery property, and then decoding starts followed by the decryption, and then the reconstruction process is done to get the original image by the receiver. The wireless channels used to transmit the MIMO visual data from transmitter to receiver are Rayleigh and AWGN in the presence of noises. By using the MIMO channel with full-duplex access, the reliability and data rate of the system improved. BPSK modulation coding, the proposed model executes with 2×2 MU-MIMO channels allowed to access in the full-duplex channel with 1024 bits in single packet size. This process carried by a BPSK modulation scheme evaluating considering two users at a time.

Providence of compressed security in one-way image transmission

Let us consider the image I_m which has to be transmitted by the users is given by the Eq. (1) as

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

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 the 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 Eq. (1), 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

$$C = \alpha\bar{\omega}I_m. \quad (2)$$

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

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

$$\mathbf{P_{ij}} = \begin{bmatrix} a_1 & a_2 & \dots & a_m \\ b_1 & b_2 & \dots & b_m \\ z_1 & z_2 & \dots & z_m \end{bmatrix}. \quad (3)$$

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 $\overline{\boldsymbol{\omega}}_\mathbf{1}$ 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

$$\overline{\boldsymbol{\omega}}_\mathbf{1} = \frac{1}{N}\sum_{i=1}^{N} f\left(P_i, P_{ij}, \tau, \cup\right). \quad (4)$$

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. The module determines a sub-set of the covariates (Eq. 4) 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 that stimulates specific coefficients to be set to zero.

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 mechanism which explained in the following section.

Step 3 Construction of the security matrix

The security matrix having a 2-D discrete-time dynamical system obtained from the Eq. (5) 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 (Stoyanov 2016; Alshibani and Ibrahim 2015; Yuan 2011; Pappachan and Baby 2015), are given by the equations

$$a_{i+1} = a_i^2 - b_i^2 + pa_i + qb_i. \quad (5)$$

$$b_{i+1} = 2a_ib_i + ra_i + sb_i. \quad (6)$$

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 (Eqs. 5, 6) of the tinkering bell leads to a pixel in the encrypted form and provide confusing information about the data, and hence making it more complicated for the attackers. To produce the compressed secured form of an image, the following mathematical evaluation is carried out. The selection of a security matrix can decrypt the inverse function of the chaotic values of the tinkering bell. By knowing the initial chaotic values, the decryption of the matrix performed by initially values. The utilization of the regression techniques and the chaotic values of the tinkering bell, the construction for the security matrix carried out, decrypting the chaotic values their confusion and diffusion property with the features. The pixel values are encrypted and secure every value in the image pixel from the attackers, we used 2D Tinkerbell map generation for the transformation of the pixel values into the chaotic values, and hence all the pixels get encrypted to protect the image data from the attacker.

Step 4 Creation of compressed secured image

By the designed scenarios mentioned earlier, the input from the image in Eq. (1), the matrix formed by the random measurable in Eq. (5), and the chaotic values obtained in Eqs. (5) and (6) get multiplied and form the compressed secured matrix output given by Eq. (7) as

$$\mathbf{c_i} = \begin{bmatrix} a_i \\ b_i \end{bmatrix} \left[\frac{1}{N} \sum_{i=1}^{N} f\left(p_{ij}, x_i, \tau, \nu\right) \right] \begin{bmatrix} P_{11} \\ P_{12} \\ P_{1j} \end{bmatrix}. \tag{7}$$

By the above Eq. (7), the obtained matrix is in the compressed form of:

$$\mathbf{c_i} = \begin{bmatrix} c_{11} \\ c_{12} \\ c_{1j} \end{bmatrix}. \tag{8}$$

Thus as stated earlier, the image compressed in the single matrix leads to the reduced number of bits, which in turn produces energy-efficient transmission with less utilization of bandwidth. Furthermore, by the transformation of the pixel values into the chaotic values, all the pixels encrypted, thus protecting the image data from the attackers. As observed in Fig. 4, firstly the image which required transmit from user 1 to user 2 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 required to transmit to user 2 via the noisy MIMI channel so that user 2 can receive the image of user 1.

Transmission of the image via MIMO channel

To improve framework limit and consistent quality, the module utilizes the MIMO strategy. With the advancement of wireless channels, MIMO, and impedance cancellation systems, it is likely to understand the cooperative transmission on a similar band. Moreover, the hidden terminal issue, jam issue caused by MAC, and the expansive delay issue in the multi-jump remote system penetrated in the MIMO.

Manchester encoding describes the cancellation at the center of every piece interim for both synchronization and bit description. By utilizing individual progress for a twofold reason, Manchester encoding achieves a similar dimension of synchronization like RZ with two dimensions of the sufficiency. In that capacity that of existing coding strategies, the Manchester code trails an algorithm for information encoding. This algorithm executes as pursues: The portrayal of information is that of line changes. A rationale 0 is demonstrated by progress from HIGH to LOW and a logic 1 is as vice versa. The representation of Manchester encoder is given by:

$$K(t) = c_i \oplus CL. \tag{9}$$

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

$$\emptyset(t) = K(t)\sqrt{\frac{2}{b_s}\cos\left(2\pi q_c t\right)}, \tag{10}$$

where q_c frequency term, and b_s is the number of bits every second. For the transmission, the framework includes two hubs; every hub has two radio wires that can transmit and get information. As far as one hub goes, the MIMO performs signature generation that transforms the digital sign into two parts. This system enables the node to transmit and receive packets at the same time and can improve the system's unwavering quality and information rate through extra coding and space with different variety of procedures. After modulating the signal, they are transmitted through the Rayleigh blurring 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.

Reconstruction of compressed security in one-way transmission of image

After transmitting the modulated image signal into the MIMO channel with full-duplex access, the received signal

Fig. 4 Input images

from the channel with the addition of AWGN into the Rayleigh fading channel is given by the expression

$$\emptyset(t) = \emptyset(t) + e. \tag{11}$$

Utilizing Eq. (11), the signal gets demodulated by the BPSK that is provided by

$$\widehat{K(t)} = \frac{\widehat{\emptyset(t)}}{\sqrt{\frac{2}{b_s}\cos\left(2\pi q_c t\right)}}. \tag{12}$$

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 Eq. (9) as

$$\hat{c} = CL \oplus \widehat{K(t)}. \tag{13}$$

Now the original modulated signal is decoded. Furthermore, to retrieve the original image, the following systematic procedures utilized by separating each matrix to obtain the original image. The selection of a security matrix decrypt by the inverse function of the chaotic values of the tinkering bell. By knowing the initial chaotic values, the decryption of the matrix performed as:

$$\hat{\alpha} = \begin{bmatrix} a_i \\ b_i \end{bmatrix}^{-1}. \tag{14}$$

Then the random matrix, which was obtained by the condition of the regression principle given by:

$$\bar{\omega} = \min_{t\nu}\left[\frac{1}{N}\sum_{i=1}^{N} f\left(P_{ij}, C_{ij}, \tau, \nu\right)\right]. \tag{15}$$

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

$$I_n = \frac{\hat{c}_1}{\hat{\omega}\hat{\alpha}} \tag{16}$$

where I_n is the original image reconstructed by the proposed module.

To decrypt the image and the reconstruction of the compressed secured matrix carried out, at which the inverse calculation for the chaotic values of the tinkering bell calculated initially and then using the prediction of the regression principle, the random matrix reconstructed accurately. This principle helps to get the original image at the receiver end. The process is further demonstrated in Fig. 6.

The image transmitted from user 1 to user 2, owing to the high number of bits to achieve energy-efficiency, optimum bandwidth utilization, and minimum transmission delay. To achieve the efficiency, image Im required to use compressive sensing (CS) to select the random measurement as the improper selection of the random measure leads to imperfect retrieval of the image. The image is encrypted and makes every value in the image pixel protected from the attackers. The chaotic values tinkering bell makes the pixel in the encrypted form and provides confusing information about the data, thereby making more complications for the attackers. The transmitted through the Rayleigh fading channel and 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 the transmission in the MIMO channel that is allowed to access in the full-duplex channel which makes to communicate in both directions. While transmitting through the channel, the additive white Gaussian noise (AWGN) additional with Rayleigh fading channel gets added, so it could be appropriately filtered in the reconstruction phase to recover the original encoded bits. Accordingly, in this proposed module, the usage of mid-rate bit coding of Manchester can recover the original bits with their clock recovery property by knowing the original bits state and added noise state. 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 Raleigh fading channel, and all the processing in received node will be reflection process to reconstruction original image. Figure 7 represents the entire process discussed above. The overall algorithm for the proposed module 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 $b_{i+1} = 2a_ib_i + ra_i + sb_i$.

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. $\widehat{c_\imath} = CL \oplus \widehat{K}(t)$

End,
Reconstruct the matrix,
decrypt by the inverse function of the chaotic values of tinkering bell
If, $\widehat{\alpha} = \begin{bmatrix} a_i \\ b_i \end{bmatrix}^{-1}$
Get decode the random matrix, which was obtained

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

The output original image obtained in the reconstruction

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

End

Using the proposed approach, the large number 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 complicated 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

Table 1 Performance evaluation for the proposed module in terms of PSNR, and processing time and BER

Images	PSNR (dB)	Processing time (s)	BER
Couple	41.76	1.405	0.003052
Barbara	41.77	1.420	0.003089
Cameraman	33.75	1.523	0.003022
Lena	41.94	1.452	0.003032
Man	41.14	1.507	0.003084
Ship	42.38	1.563	0.003062

Table 2 Performance of SSIM

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

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. Due to the combined module, the additional computation time required for secondary processes neglected and hence increasing the speed of the transmission. The image becomes more compatible with the channel bandwidth and transmits securely with minimum computation time by the compressed security matrix.

Results and discussion

To present the effectiveness of the proposed module regarding energy efficiency, time-consuming, and security, the simulation is carried out in MATLAB using the images of the digital image processing book. This section presents those results.

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 Fig. 4.

Step 2 Selection of random matrix

For the selection of the random variables regression principles carried out for the input images, 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 carried out.

Step 4 Transmission of compressed secured image

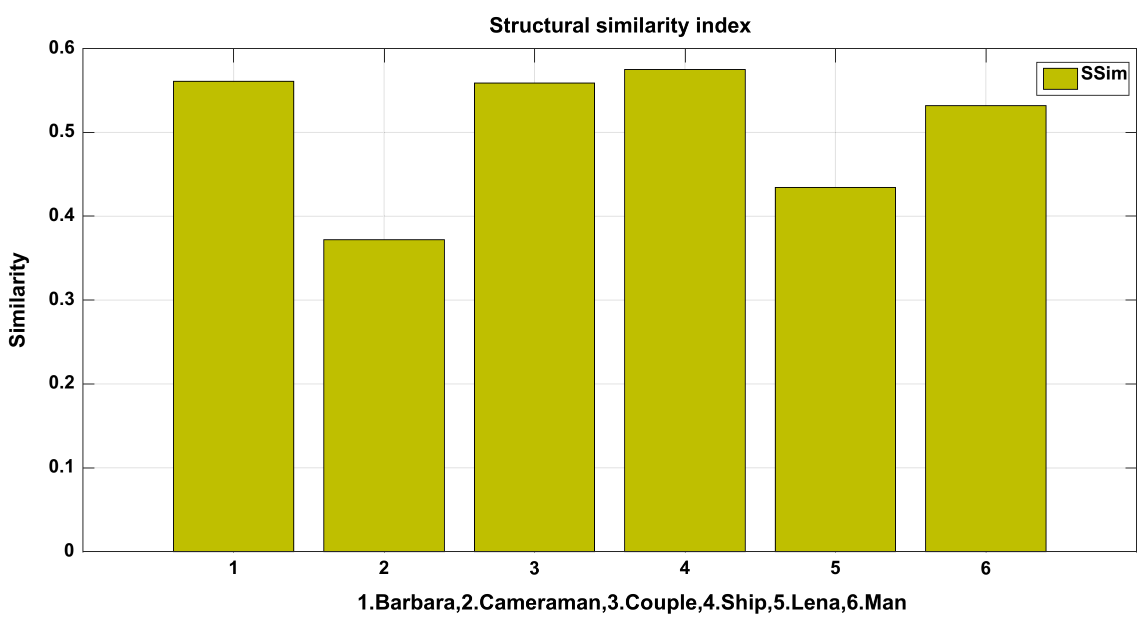

Fig. 5 Structure similarity index measurement for the six input images

Table 3 Comparison of PSNR with the existing techniques

Algorithm	PSNR (dB)
Hybrid watermarking (Singh et al. 2016)	28.3
Al-Hayani and Ilhan (2020a)	30.81
Lecuire et al. (2008)	31
Nasri et al. (2010)	20
Ur Rehman et al. (2016)	29.88
Proposal method	41.6

Table 4 Comparison of communication time with the existing techniques

Methods	Time consumption (ms)
JPEG2000	366
SS	900
DCT	473
SPIHT	331
JPEG	544
Proposed	275

The process is executed on considering specific parameters. The proposed model with 2 × 2 MU-MIMO channels beside 1024 bits as a packet size. This process carried by the BPSK modulation scheme evaluating with two users, considering users at a time. When the above signals are transmitted through the channel, the added white Gaussian noise incorporated. After the addition of those noises, the signals are altered. 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 in the radio communication channel, the estimation of the BER carried out to recover the original signal encoded by the Manchester coding. The clock recovery of Manchester used to decode the original signal. Furthermore, using the predictive and integrality function of the regression principle, the random variables selected in the initial stage are recovered. It is proved that using the proposed model, the input image which is transmitted by the user through the fading channel becomes compressed, secured, and occupies less energy and finally reconstructs the output image as of the input image. Then to assess the efficiency of the proposed module, seven parameters are evaluated in the below section.

Performance evaluation

This section presents the performance evaluation proposed approach in terms of PSNR, SNR, channel capacity, BER, time, etc. Some of the formulas of performance metrics already presented in previous papers; other than that, we measured below performance metrics as well.

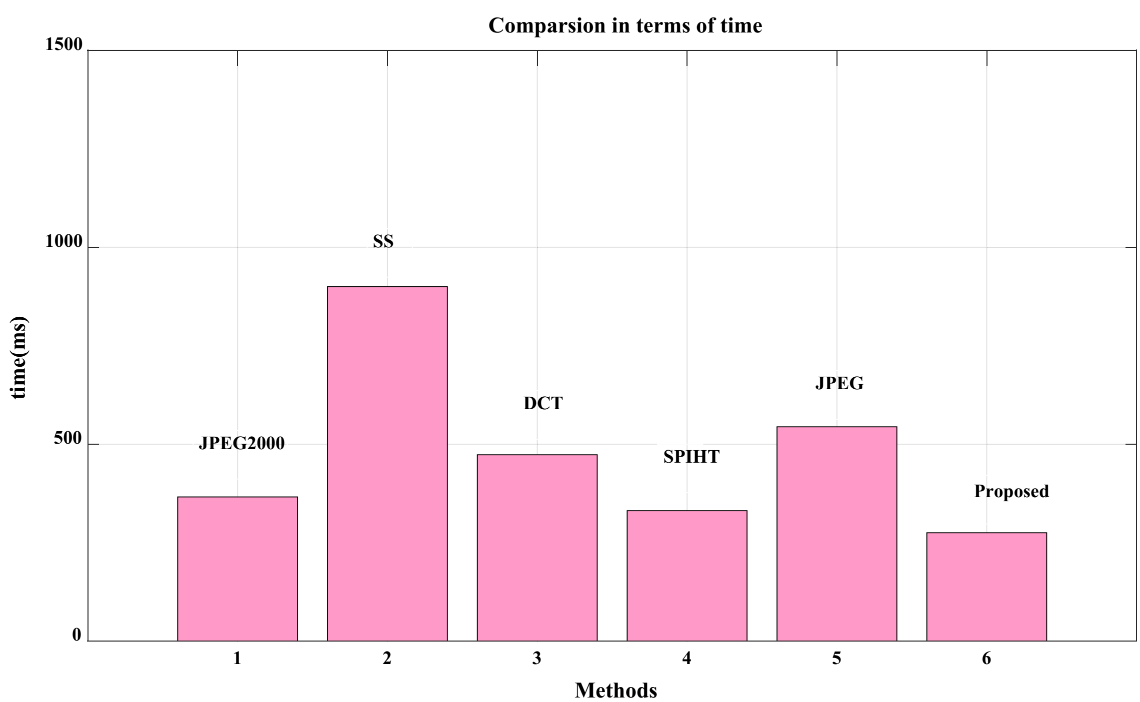

Fig. 6 Comparison of communication time with the existing techniques

Table 5 Comparison of energy consumption with the existing techniques

Methods	Energy consumption (mJ)	% Energy saving
Lecuire et al. (2008)	1252.6	87.47
Nasri et al. (2010)	1252.6	87.47
Ur Rehman et al. (2016)	411.3	95.88
Proposed	383.6	97.54

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.

MSE The mean square mistake between the main image transmitted from the transmitter and received imaged at the receiver is computed as:

$$\mathrm{MSE} = \frac{\sum_{\mathrm{M.N}} \left[\mathrm{I}_1(\mathrm{m,n}) - \mathrm{I}_2(\mathrm{m,n})\right]^2}{\mathrm{M} * \mathrm{N}}. \tag{17}$$

Root mean squared error (RMSE) Root means square was dictated by taking the root of MSE.

$$RMSE = \sqrt{MSE}. \tag{18}$$

BER The bit error rate (BER) is the number of bit blunders per unit time. The bit mistake degree (additionally BER) is the number of bit blunders partitioned by all dwarf of moving bits during an examined time between time. It is computed as:

$$\mathrm{BER} = \mathrm{N}_{\mathrm{err}}/\mathrm{N}_{\mathrm{bit}} \tag{19}$$

where M is the number of signals, $\mathrm{M}=2^{\mathrm{k}}$, k is the number of bits transmitted.

Signal to noise ratio (SNR) SNR is portrayed as the extent of normal sign an incentive to the standard deviation of the foundation esteems. Signal to noise ratio (SNR) can be used as an extent of sensitivity. The value becomes normalized when the SNR gets divided by its dimensions:

$$\mathrm{SNR} = \mu_{\mathrm{xy}}/\sigma_{\mathrm{xy}} \tag{20}$$

where μ is the average among the image pixels x, y, σ is the standard deviation of the pixels of the foundation (commotion).

From the above results, parameters such as PSNR, BER, and processing time of the proposed model shows the better for 6 different images. The average results of PSNR are 40.46, whereas the average BER is approximately 0.003 due to the effective design of the high-quality image received. Using the compressed security matrix and the full-duplex access for the transmission, a fast transmission speed of 1.47 s achieved (Table 1).

The structure similarity index measurement is computed as:

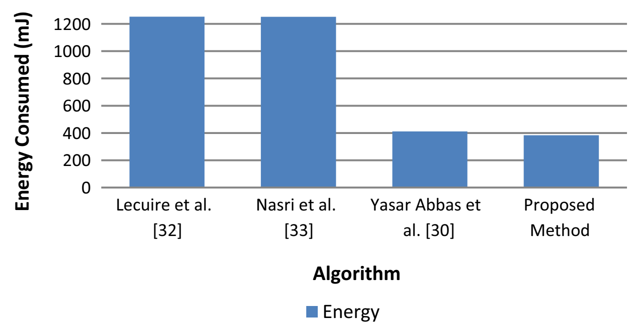

Fig. 7 Average energy consumed analyses

$$SSIM = [l(x,y)]^2 * [c(x,y)]^2 * [s(x,y)]^2 \tag{21}$$

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 2 (Fig. 5) describes the structural similarity index measurement (SSIM) obtained for the six input images, the maximal SSIM was seen for the Couple image and the least for Cameraman (Table 3).

State-of-art evaluations

The proposed methodology compared with the existing methodology of Singh et al. 2016, hybrid watermarking, Lecuire et al. 2008; Nasri et al. 2010; and Ur Rehman et al. 2016. The proposed methodology compared with five state-of-art methodologies in terms of average PSNR values in Table 5. The proposed method with a PSNR value of 41.6 dB claims that the proposed system works well compared to existing methods. Communication time denotes the total time consumed for the communication process for transmitting the user data from one place to another.

From Table 4 (Fig. 6) describes the proposed methodology compared with the other existing methodology in terms of their communication time. Comparing the proposed method, it maintains the value of 275 ms (ms) and showing that due to the proper modulation and transmission, the module becomes effective and possesses low communication time. The adaptive CS compression method presented in this paper shows the better. We observe that Table 5 comparison with our proposal methodology, the performance is compared (CS) with JPEG, JPEG2000 methods. The JPEG method shows the worst performance in terms of their communication time. It seems that the existing methods of JPEG2000, SS, DCT, SPIHT, JPEG possess 366, 900, 473, 331, 544 ms (ms) respectively. Comparing the proposed method, it possesses the value of 275 ms (mJ) and showing that due to the proper modulation and by transmission energy consumption (mJ). And energy-saving, The advantage of DWT, EBCOT techniques in JPEG2000 leads the improved CR in the proposed MIMO image transmission model. Compression technique required to achieve the trade-offs between the parameters compression image algorithms like (CS, JPEJ2000, JPEG.) and image quality performance metrics especially for image compression. CR as compared to all conventional methods in other references like Lecuire et al. (2008) and Nasri et al. (2010) as below table.

The proposed methodology compared with the existing methods regarding energy utilization and energy saving in table Fig. 7 (Table 5). It is noticed that the proposed methodology produces high energy efficiency and low energy saving. The proposed methodology consumes energy of 383.6 mJ and saves 97.54% energy, showing the efficient energy utilization. It is expected that all sensor nodes initial energy is assigned to 0.5 joules. After sensor nodes involved in the process of image transmission, the receiving and transmitting energy consumed 383.6 (mJ). After the complete transmission of energy from source to destination nodes, the average energy utilization of all sensor hubs in the system is measured. The total numbers of sensor nodes are 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 reduction in the number of transmissions in the proposed model; hence the performance is optimized for energy efficiency compared to the state-of-art methods.

Conclusion

The challenging research problem of intelligent visual sensing system regarding to energy-efficiency and security are solved in this paper using the full-duplex MIMO communication standards.

The proposed module designed using a compressed security matrix technique to enhance the security against the various threats. Furthermore, the noise cancellation introduced to remove the unwanted noisy data from the received image. Paper presented the complete design and experimental evaluation of the proposed model compared to recent methods of one-way image transmission. The evaluation and comparison results demonstrated that the proposed module enhanced channel capacity and reduced the BER value compared to the other techniques. Similarly, we presented the proposed method evaluation in terms of PSNR, SSIM, and processing time compared to other methods. All outcomes claim that the proposed model achieves the higher security with minimum computational efforts and higher image quality.

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