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ECC Image Encryption Scheme using Whale Optimization Technique

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Abstract: Through the simultaneous integration of the tangible and immaterial realms, the Internet of Things (IoT) generates integrated communication scenarios for network devices and stages. Encryption technologies that provide security to transmitted pictures across the connected networks of the two parties were one of the significant open difficulties in bolstering IoT security that the study's researchers recognised and analysed. The device is based on a hybrid algorithm that uses optimisation and encryption strategies. This proposed picture safety model encryption made use of the Whale Optimisation technique. By following the suggested strategy, optimisation in encryption techniques aims to choose the most advantageous keys for encryption algorithms. Following implementation, the results are evaluated using the Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE). If the proposed technique outperforms the current approaches, then the recommendation is considered a success.

Elliptic curve cryptography, optimising for whales, and image security are among of the keywords.

Introduction

An outstanding method for delivering several recipients from a single IP datagram source is multicasting Internet Protocol (IP). With the proliferation of high-speed Internet, multicasting IP has become more popular as a means of group communication for uses such as real-time video delivery. Multicast IP vulnerabilities may be caused by a number of security flaws, which is why more and more organisations are relying on multicast IP to distribute information. Any server, for instance, may send an IGMP message to its closest router and join a multicast group, which makes the job difficult. One of the methods proposed to avoid vulnerabilities is encrypting data using group keys[2][3]. The Every member of the group, including the sender, shares a single key, which is called the group key. For the purpose of encrypting both the sender's and the recipients' communications, group keys are crucial. Group key management must adhere to security standards such as reverse secrecy[4] and call confidentiality [5] [6]. This criteria is put in place to ensure that no one other than authorised team members may decipher the data. Secure communication is not available to those who have left the Multicast Group at this time [7]. New members joining the Multicast group will not be able to access messages made before they joined in reverse. In order to meet the requirements, group keys must be securely assigned to approved members and updated if there is a change in membership. This process is known as the lock or restart group. It usually takes more computations and communications overhead to rewrite after leaving a group compared to joining a group. This is due to the fact that when a new member is added to a group, the updated group key may be delivered to both the current members via multicast communication, encrypted with the old key, and to the new member through unicast using the private key. references [8] through [10]. There have been many descriptions of re-keying strategies for secure multicast up till recently[11][12]. Departure group key distribution computational and communication cost reduction is a primary motivation for these techniques. Having said that, there have been issues with each of them. Distribution of group keys to members during joins is the primary emphasis of the techniques proposed in [8]. The group key is updated after a predetermined duration in references [13] and [14]. Consequently, these methods do not provide true forward and backward secrecy. Multiple subgroups are created from the multicast group in the solutions given in [15]. It is the responsibility of a designated subgroup controller to generate keys for their own subgroup. When a subgroup enters or quits, just that subgroup modifies its local key. The troublesome rekeying procedure that occurs when a group member departs is one drawback of these protocols. This research offers the following contributions in response to this issue. To encrypt data, experts employ the Elliptic Curve Cryptography (ECC) technique. This approach selects the private key for every member of the group using the Whale Optimisation approach (WOA). This effective cryptographic method guarantees secure communication in a multicast group. The key server not only generates the private key but also its inverse value [18]. Using the public keys of all members and the group controller, the key server creates a shared group key. In order to facilitate cooperative operation, the key server generates a new private key and the inverse value for the new member. After then, the updated group key is sent out over multicast. to every member of the subgroup and broadcast to any new members via unicast. Key servers do not generate new group keys but instead inform the remaining members of the subgroup of the inverse value of the deceased member's value. When a member leaves a group, their inverse value is applied to the group keys of the other members who are still there. The computational cost of the rekeying operation will be reduced by following this technique [19].

Related works

Secure group core management has been the focus of a number of earlier publications in this field. A mobile network is comprised of several wirelessly communicating mobile devices. Worries about security become more complicated when volatility is present. A discussion of safe group key management for the ever-changing peer groups in mobile wireless networks is given by Sukin et al. [20]. One of the biggest issues with secure group chat is people exchanging passwords. In order to accommodate the dynamic nature of networks and the frequent changes in membership, innovative team switching programmes and efficient recording systems have been developed. This technique provides greater leeway in case the group dynamically changes, while still establishing the group key. The proposed project was a success in terms of independence of keys, validation of keys, forward or backward secrecy, and team secrecy. Utilising the proposed idea might result in top-notch multicast security on mobile networks. In order to reduce the cost of calculating the master key server (KS) during key updates, Kumar et al.[21] proposed a more efficient central group centralised group key distribution (CGKD). The processing cost is decreased when a member joins by adding, multiplying, and subtracting, playing a game, and making an image, as well as by deleting. In addition, the proposed method simplifies KS storage. Furthermore, a dual-policy-based CGKD protocol extension has been created to deal with significant member turnover. Our results showed that the proposed method outperformed the control group in terms of KS overload and group participation. For effective team distribution and management over various internet technologies and ad hoc networks, Veltri et al.[22] laid forth a paradigm. Reduced network traffic and overheads due to user-induced changes in team composition are the goals of the proposed method. Some of the many possible uses for recommended mapping scenarios include safe online data storage and encrypted communications in vehicle networks. In the proposed approach, a focal point is used. When several adverse things happen at once, only then does clear communication between the KDC and the team member become necessary. As a result, the suggested technique is able to outperform current content creation algorithms. The manner group-level privacy and integrity are offered has improved. In a dynamic team atmosphere, the racking process goes even farther. As a result, creating an effective team ethics pact is critical. Muhammad Bilal and Shin-Gak Kang [23]established a novel approach for determining a major group agreement based on the official vectors of team members. The proposed project is split,but it does not need team synchronization to unlock and update keys. Furthermore, the system employs the most up-to-date multicast keys for effectively safe machine connections in subgroups. In terms of communication and compatibility, the recommended protocols proven to be successful and efficient. KeyDer-GKM and ReEnc-GKM are two provably secure and practical schemes proposed by Yi-Ruei Chen and Wen-Guey Tzeng [24]. By outsourcing protocol-N operations, the ReEnc-GKM technique allows a member to lower the cost of determining the current group key for encryption. Joint assaults are not possible in any of the suggested systems. The success of the projects is dependent on the ability of the trusted team manager to manage the whole organization and hand over the keys. The centralized approach is not ideal for large sensors and B2B networks since network structure, range, and dynamics are unknown at the start of construction. It was more efficient than previous techniques since the suggested technique can only be implemented using hash and XOR operations. Alvarez et al. [25]proposed a novel technique to secure multicasting in which user groups are reentered using atechnique for calculating GCD based on the Euclid algorithm. The proposed method considers user tree structure, which, when used as a whole, decreases bandwidth needs and proves that IT demands are less than those of competing methods. Teams under the supervision of a manager have developed a distributed protocol to improve the security of distributed data and user verification while simultaneously reducing the number of incoming messages sent by a centralised technique. We have seen better results with the presented methods in terms of data breaches and IT requirements. On page 26, S. Jabean Begum and T. Purushothaman laid forth a method for group communication. A new decentralised multicast key management system named Cluster Optimal Cluster Hierarchical Tree (OCHT) has been introduced to provide stability, scalability, and cost-effectiveness. The new decentralised OCHT-based solutions beat a number of competitors in memory, packet transfer speed, performance, power consumption, and end-to-end latency.conventional methods. The suggested strategy was perfect for moving the cluster head in the near future, therefore the reorganisation time was far less than with conventional approaches. In order to ensure the security of Internet communications, Kumari et al. (2018)[27] investigated the crucial role that a robust verification scheme plays. With the suggested ECC technique, attacks that impersonate clients or servers would fail. Client confidentiality and shared authentication are also not part of their plan. There have been many proposals for picture encryption processes that aim to guarantee data secrecy. These limitations need to be considered by the suggested method. Shaheen et al. [28] state that traditional cryptosystems cannot be linked to the WSN since most of the presented methods are structurally and estimatively unsuitable for advanced pictures.

Proposed method

In order to transmit an initial, secret picture from one party to another, the proposed image encryption technology is used. A distinct RGB matrix is created by extracting the pixel values of the source image's RGB pixels. Following this, the picture is partitioned into blocks prior to the encryption step[8][29]. The encryption method used to secure each block's matrix is the ECC approach. Then, the new pixel value is used to replace the old one in every block. The original picture may be hidden while the scrambled one is obtained using this procedure. After the encryption process is finished, the encrypted picture is decoded by using the opposite encryption method [30]. Optimisation of the private key generation technique was carried over into the decryption process via the WOA algorithm. Once the optimised key generation phase is over, the image's output is used as a health metric to determine the Peak Signal to Noise Ratio (PSNR) value. Finding the optimal PSNR value for a private key is the first step towards keeping it in top shape. After the decryption process is finished, the PSNR, MSE, and Correlation Coefficient (CC) are used to compare the original picture with the final output image in order to evaluate correctness. This method ensures the secure transfer of the original picture while protecting the privacy of the original data.

3.1. Elliptical Curve Cryptography (ECC)

Asymmetric key cryptography makes use of public key cryptography in several ways, and ECC is one of those ways[31][32][33]. Following this process yields the upper bound with a constant The end product is symbolised by the Cij in this procedure. The suggested WOA method outperforms the state-of-the-art ECC method in terms of optimised values, and it is used to generate the secret key (H) throughout the decryption phase [35].

3.2 Whale Optimization Algorithm (WOA)

A heuristic method which takes biological processes into consideration has been developed by SeyedaliMirjalili and Andrew Lewis in 2016 and is referred to as the whale optimization algorithm (WOA)[36].WOA is a particular humpback hunting method optimization algorithm, which emulates the unique humpback hunting technique.The unique optimization methodology allows WOA to have a very good global search capacity. ECC based on the WOA is recommended for optimal custom key selection[37].The WOA is inspired by the humpback whale's distinctive hunting technique known as bubble-net predation. The humpback whale is capable of sensing the distance between himself and his prey and surrounding it. It is noticed that the humpback whale may ascend in a spiral pattern to a depth of around 15 meters and spit out a variety of different-sized bubbles. The last and initial spat out bubbles came to the surface simultaneously, forming a cylindrical or tubular bubble network. It prefers a massive spider- knotted web that closely surrounds the prey and draws it into the center of the net. Thus, the almost upright humpback whales open their mouths in the bubble circle and ingest the animals in the net. The humpback whale's hunting activity may be classified into three stages, as described above: surrounding prey, spiral bubble-net feeding maneuver, and looking for prey[38].

Bubble-net attacking strategy

Humpback whales are capable of determining their prey's location and attacking it in a diminishing circular fashion. Because the optimal solution is unknown at the outset of the optimization problem, WOA assumed that the current best candidate solution is the prey or something near to it. The other search agents attempt to improve their rankings in relation to the best search agent. To mimic the strategy of surrounding the prey, the following mathematical equations are used:

$$D = C.B - x^t$$

$$x^{t+1} = B - A.D$$

$$A = 2a.r - a$$

$$C = 2.r$$

Where D is the distance between the current search agent x^t and the best search agent B at t iteration. Note that, the best search agent is updated across iterations is there is a better search agent.A is a random value in the range [a, a], and a decreases from 2 to 0, indicating that the newlocation of the search agent can be updated anywhere between the current location and the location of the best search agent. C is a constant. The following equations are used to mimic the behavior of a spiral-shaped path:

$$x^{t+1} = D'.e^{bl}.\cos(2\pi l) + B$$

$$D' = |B - x^t|$$

Where D' denotes the absolute value of the distance between the current search agent and the best search agent at a given iteration. b is a constant that specifies the logarithmic spiral's form. l is a random number between $[-1,1]$. As humpback whales swim in a diminishing circle and in a spiral-shaped course, WOA employs both behaviors with an equal chance of 50%:

$$x^{t+1} = \begin{cases} D'.e^{bl}.\cos(2\pi l) + B & p \le 0.5 \\ B - A.D & p < 0.5 \end{cases}$$

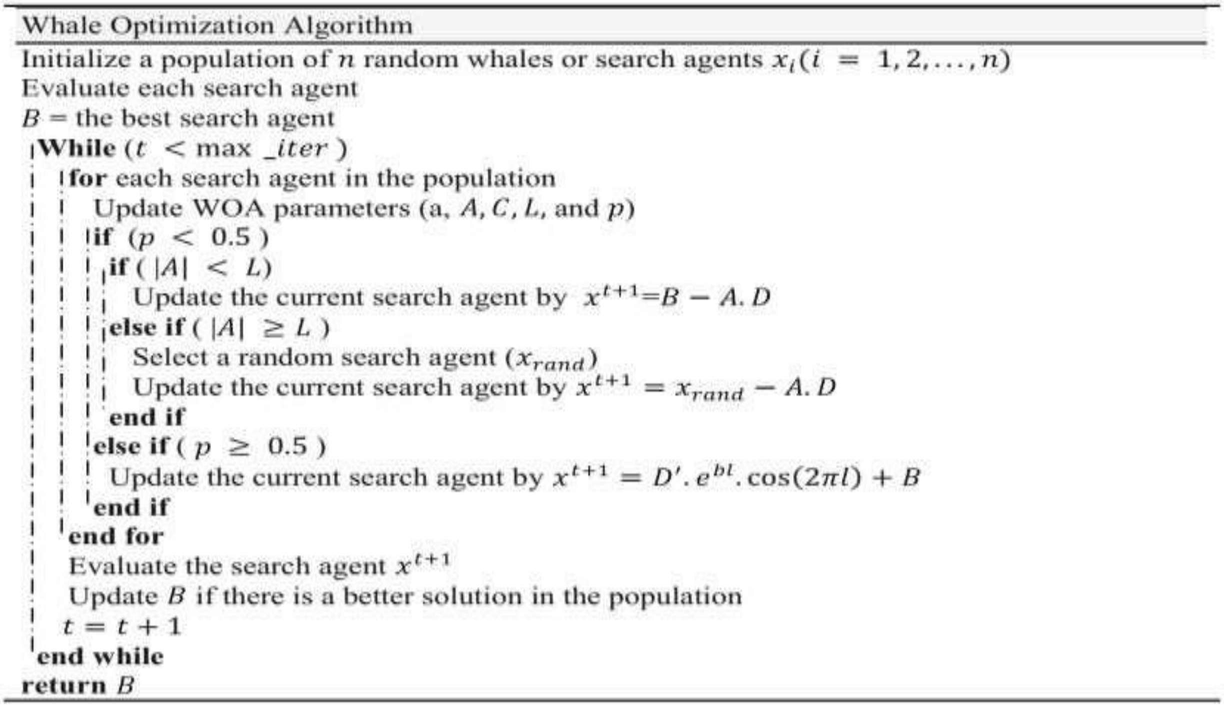
Searching for the prey

To simulate the humpback whales' random search for prey, A is employed with random values higher than 1 or less than -1.Exploration may be accomplished by the use of a random search agent, but exploitation may be accomplished with the use of the best search agent, as in the bubble-net technique. Mathematically, hunting for prey may be stated as:

$$D = C.x_{rand} - x^t$$

$$x^{t+1} = x_{rand} - A.D$$

Where x_{rand} is a randomly picked search agent from the population. The pseudocode for WOA is shown in Algorithm 1



```
Whale Optimization Algorithm
Initialize a population of $n$ random whales or search agents $x_i (i = 1, 2, \ldots, n)$
Evaluate each search agent
$B$ = the best search agent
While ($t$ < max _$iter$ )
    for each search agent in the population
        Update WOA parameters (a, $A, C, L$, and $p$)
        if ($p < 0.5$ )
            if ( $|A| < L$)
                Update the current search agent by $x^{t+1} = B - A.D$
            else if ( $|A| \geq L$ )
                Select a random search agent ($x_{rand}$)
                Update the current search agent by $x^{t+1} = x_{rand} - A.D$
            end if
        else if ( $p \geq 0.5$ )
            Update the current search agent by $x^{t+1} = D'.e^{bl}.\cos(2\pi l) + B$
        end if
    end for
    Evaluate the search agent $x^{t+1}$
    Update $B$ if there is a better solution in the population
    $t = t + 1$
end while
return $B$
```

Results and Discussion

The proposed ECC-WAO-based image security procedure was built in MATLAB 2018 using an i5 CPU and 8 GB RAM configuration. The suggested model's results are compared to those of previous studies and generic optimization approaches in this article. This analysis model takes into account several standard images, including Lena, baboon, home, barbaraimages and utilizes performance metrics such as PSNR, MSE, and CC.

The suggested ECC-WOA based offer made encryption architecture is demonstrated in Tables 1, 2 and 3. In hidden image, an RGB band was formed and each band included two scrambled and decoded offers. Security examinations include histogram analysis, correlation analysis, and entropy analysis [30]. This inquiry includes the highest severe PSNR value of 53.42 dB in unscrambled images, which corresponds to previous image exhibits. At any point, the correlation value is low, indicating that the encryption technique achieved a high degree of randomness between neighboring pixels in the scrambled image in CC. The data indicate that the image is more efficiently executed in terms of time since it is less fragmented. However, the PSNR suggested that a more original figure in primate image two-some to a greater number of squares, which results in an increase in the length of a number of chains, so achieving elite insecurity.

Table 1

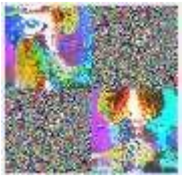
Input Image	Color band	Share creation	Combined Sharing	Encryption	Decryption	Reconstruct image
	R1					
	G1					
	B1					
	R2					
	G2					
	B2					

Table 2

Input Image	Color band	Share creation	Combined Sharing	Encryption	Decryption	Reconstructed Output
	R1					
	G1					
	B1					
	R2					
	G2					
	B2					

Table 3

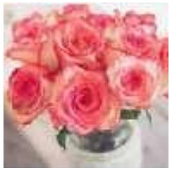
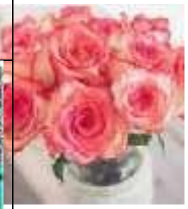
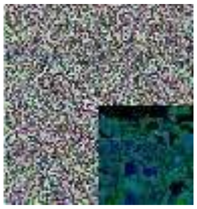
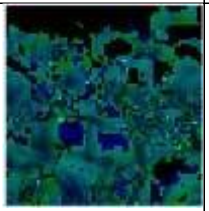
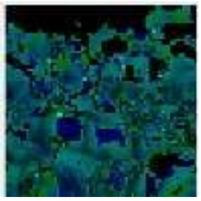
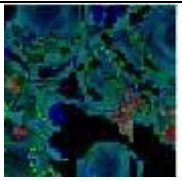
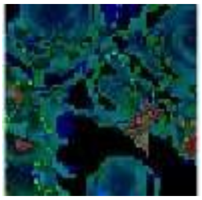
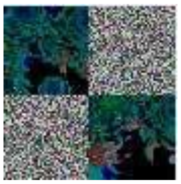
Input Image	Color band	Share creation	Combined Sharing	Encryption	Decryption	Reconstructed Output
	R1					
	G1					
	B1					
	R2					
	G2					
	B2					

Table 4

Input	Method	PSNR	MSE	CC
	ECC	46.54	1.54	0.9
	WOA	54.02	0.26	1
	ECC	45.94	1.67	0.9
	WOA	53.24	0.31	1
	ECC	46.96	1.36	0.9
	WOA	53.29	0.3	1
	ECC	46.07	1.62	0.9
	WOA	52.94	0.33	1
	ECC	46.23	1.56	0.9
	WOA	52.5	0.37	1
	ECC	46.61	1.43	0.9
	WOA	52.84	0.37	1
	ECC	46.35	1.52	0.9
	WOA	52.14	0.42	1

Table 4 shows a comparison between the ECC approach and the suggested ECC with WOA method for several pictures, including Baboon, Lena, flower, boat, Barbara, fingerprint, and eye images, utilising PSNR, MSE, and CC values. Since the suggested method's PSNR value is higher than the ECC algorithm's, the picture quality was enhanced, as shown in the table. The proposed method of picture encryption delivers a satisfactory degree of security, according to the comparative analysis. The results show that the suggested method is superior to the ECC method.

5. Conclusion

An optimised picture encryption scheme based on ECC and the WOA method is presented in the study. The proposed approach clearly yields a superior picture, as shown by an average PSNR value of 54.02 between the first and final photos. The averageAdditionally, the square error is minimised across all photographs, indicating that the correlation coefficient is close to 1 in the majority of the shots. The analysis of histograms and correlation coefficients clearly shows that the encryption procedure is unaffected and protects the secret image's secrecy [39] [40]. Based on the results of the comparison, the proposed method provides better encryption and higher PSNR values than ECC. We will test the proposed method's robustness against salt and pepper, filtering, cropping, and blurring assaults in the next steps.

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This sentence is paraphrased from an article published in 2018 in the journal Symmetry (Basel) by W. Z. Sun, J. S. Wang, and X. Wei. The article is titled "An improved whale optimisation algorithm based on different searching paths and perceptual disturbance" and has the DOI 10.3390/sym10060210.

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