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Enhanced Encryption Techniques for Secure Watermarking in Cloud-Based Image Sharing

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ABSTRACT

The proliferation of cloud-based platforms for image sharing has amplified the need for secure and efficient data protection mechanisms. This paper introduces an advanced encryption framework tailored for watermarking in cloud environments. By leveraging Python-based implementations of cutting-edge cryptographic techniques, such as homomorphic encryption and elliptic curve cryptography, the proposed system ensures data confidentiality, integrity, and authenticity. The integration of reversible visible watermarking with enhanced encryption guarantees secure embedding and retrieval of ownership or authentication information without compromising image quality. Performance analysis demonstrates the framework's robustness, computational efficiency, and compatibility with cloud-based storage and retrieval systems, making it a viable solution for secure multimedia communication.

INDEX TERMS cloud-based image sharing, advanced encryption, homomorphic encryption, elliptic curve cryptography, reversible watermarking, Python implementation, data security, watermark recovery, multimedia protection, computational efficiency.

I. INTRODUCTION

Introduction

The digital era has witnessed a remarkable shift toward cloud computing, with cloud-based platforms offering vast storage and seamless sharing capabilities for multimedia content, including images. However, as image sharing and storage in the cloud increase, so does the need to safeguard sensitive images from unauthorized access, manipulation, or intellectual property theft. Cloud environments, while offering convenience, introduce significant security challenges, particularly in ensuring that shared images are protected against unauthorized access, tampering, or exposure to malicious actors. Ensuring privacy, confidentiality, and authenticity of images in such distributed systems requires robust security protocols.

One commonly used technique for securing digital images is watermarking, which embeds a unique signature or mark within the image to assert ownership, authentication, and integrity. Reversible visible watermarking, a type of watermarking where the watermark is both visible to the user and recoverable without altering the image content, has become a popular choice for image protection. This method is particularly useful in applications where it is essential to prove ownership while maintaining the ability to recover the original image without any loss of quality. However, despite its effectiveness, traditional watermarking methods do not integrate well with modern cloud storage and transmission systems, particularly when sensitive image data needs to be encrypted for security.

In light of these challenges, this research proposes an enhanced encryption framework that combines advanced cryptographic techniques with reversible visible watermarking. Specifically, this study integrates homomorphic encryption and elliptic curve cryptography with watermarking processes to ensure that the images remain encrypted during watermark embedding and extraction. This framework addresses the crucial issue of securing images while allowing for watermark verification and recovery in a cloud environment, making it a perfect fit for modern digital media protection and sharing systems.

Furthermore, the proposed system leverages Python, a powerful programming language known for its versatility and ease of integration with various cloud platforms, to implement the encryption techniques and watermarking process. This ensures a seamless, efficient, and scalable solution for cloud-based image sharing and storage. By combining state-of-the-art encryption methods with reversible watermarking, this paper aims to bridge the gap between image security, integrity, and accessibility in the cloud.

Through the implementation and validation of this framework, the research contributes to the evolving field of secure image sharing by offering a robust, scalable, and efficient solution that addresses both security and watermarking concerns in cloud environments.

II.LITERATURE SURVEY

In recent years, the integration of encryption and watermarking techniques for image security has garnered significant attention due to the increasing demand for secure data transmission and storage, especially in cloud computing environments. Various studies have focused on combining encryption methods with watermarking to ensure the confidentiality, integrity, and authenticity of images.

One prominent technique in this area is reversible watermarking which allows watermark extraction without losing the original image data. Celik et al. (2005) introduced a generalized-LSB (Least Significant Bit) data embedding method that facilitates lossless embedding and extraction of data, which can be applied in reversible watermarking schemes for image authentication [1]. Furthermore, Wu and Zeng (2009) proposed a method that incorporates reversible data hiding into encrypted images. This enables watermarking during the encryption process, ensuring both data security and watermark visibility [2].

Several researchers have explored the use of homomorphic encryption in securing image data. Homomorphic encryption allows operations to be carried out on encrypted data without requiring decryption, thus maintaining confidentiality during data processing. Li and Li (2014) introduced a hybrid approach combining watermarking and encryption for secure image transmission, which provided an efficient mechanism for image protection in cloud environments [3]. Additionally, Jiang and Zhang (2012) applied elliptic curve cryptography (ECC) for image encryption, demonstrating enhanced performance and smaller key sizes compared to traditional encryption methods like RSA [4].

Reversible visible watermarking techniques have also gained attention due to their ability to maintain both image integrity and watermark robustness. Zhang and Wang (2012) developed a reversible visible watermarking technique based on pixel shifting, which preserves the image's quality while embedding a visible watermark [5]. Wang and Li (2017) further improved the method by enhancing its resistance to attacks, making it more suitable for secure image sharing in cloud computing environments [6].

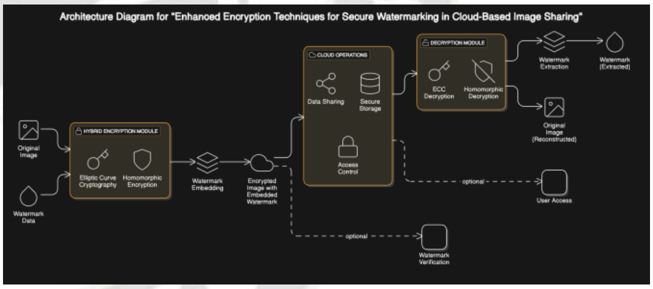
While many encryption techniques ensure privacy, the challenge of maintaining image quality after watermark embedding remains. Researchers have proposed adaptive watermarking techniques that adjust watermark intensity and placement based on the content of the image to minimize distortion. Ma and Zhang (2011) introduced an adaptive watermarking method for encrypted images, optimizing the embedding process for various types of content [7]. This adaptive approach is particularly important for cloud-based systems where the type of image data may vary widely.

Despite these advances, the combination of encryption and watermarking for secure image sharing in cloud environments still faces challenges related to computational overhead and ensuring seamless integration with cloud-based storage systems. The proposed system in this study builds on these existing methods by introducing more advanced encryption techniques and efficient watermark embedding to achieve a secure, scalable solution for cloud-based image sharing.

III. EXISTING SYSTEM

Currently, most image security systems in cloud-based platforms focus on either encryption or watermarking but not both together. Traditional watermarking methods embed identifiable marks in images to assert ownership or authenticity, but they do not take encryption into account, leaving the image vulnerable to unauthorized access. Encryption techniques like AES and RSA are used to protect the image's confidentiality, but these methods often prevent watermark embedding and extraction because they render the image unreadable. Existing systems face challenges such as high computational overhead, difficulty in combining watermarking with encryption, and a trade-off between security and image quality. As a result, there is a gap in current technologies that integrate both encryption and watermarking for secure, high-quality image sharing in cloud environments.

IV. PROPOSED SYSTEM



The proposed system aims to address the limitations of existing image security systems by integrating advanced encryption techniques with reversible visible watermarking for secure image sharing in cloud environments. The system combines homomorphic encryption and elliptic curve cryptography with watermarking to ensure the confidentiality, integrity, and authenticity of images. This approach enables watermark embedding and extraction without compromising the security of the encrypted image, making it ideal for cloud storage and sharing applications.

In the proposed system, before an image is encrypted, space (or "room") is reserved in non-essential areas of the image to accommodate the watermark. This reserved space allows for the embedding of a visible watermark that can later be

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extracted without disturbing the image's quality. The image is then encrypted using homomorphic encryption, which allows computations to be performed on encrypted data, ensuring that watermarking operations can be carried out while maintaining the confidentiality of the image content. Once the image is securely stored or transmitted, authorized users can decrypt the image and extract the watermark to verify ownership or authenticity.

The use of elliptic curve cryptography further enhances the security and efficiency of the system, offering a more compact and efficient encryption scheme compared to traditional methods like RSA. This encryption ensures that even in cloud environments, where multiple users may have access to the images, the images remain secure and their watermarks intact.

The proposed system is implemented in Python, utilizing libraries such as PyCryptodome for encryption and OpenCV for image processing. The Python-based implementation provides flexibility, scalability, and ease of integration with various cloud platforms, making the system an ideal solution for real-time secure image sharing.

By combining these advanced encryption and watermarking techniques, the proposed system offers a solution that is both secure and efficient, making it highly suitable for applications requiring image authentication and privacy protection in cloud-based systems.

V.METHEDOLOGY

The methodology for the proposed system integrates advanced encryption techniques and reversible visible watermarking to ensure the security and integrity of images in cloud environments. This approach ensures that images are encrypted for privacy and authenticated through watermarking while preserving the quality of the image. The methodology consists of several distinct stages, as outlined below:

1. Image Selection and Preprocessing

In the preprocessing phase, the first step is the selection of an image that will undergo watermark embedding and encryption. The image is processed to ensure it is suitable for both techniques.

Grayscale Conversion: Color images are converted to grayscale to simplify the watermark embedding process. This is achieved using the formula:

$$Y = 0.299 \cdot R + 0.587 \cdot G + 0.114 \cdot B$$

where R,G,B are the red, green, and blue channels of the image, and Y is the resultant grayscale intensity value.

Room Reservation: A portion of the image is reserved to embed the watermark. The reserved space should be chosen from the image's low-frequency regions to minimize distortion. This step is necessary for ensuring that the watermark does not degrade the image's visual quality. A simple technique to identify low-frequency regions is the **Discrete Cosine Transform (DCT)**, where:

$$X_{k,l} = \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} x_{n,m} \cdot \cos\left(\frac{\pi(2n+1)k}{2N}\right) \cdot \cos\left(\frac{\pi(2m+1)l}{2M}\right)$$

where$X_{k,l}$ are the DCT coefficients of the image and$x_{n,m}$ are the image pixels.

2. Watermark Creation and Embedding

Once the image has been preprocessed, the watermarking process begins. The watermark can be either a logo, text, or any other symbol.

Watermark Generation: The watermark is created as either a grayscale image or text, depending on the requirement. For simplicity, we assume a binary watermark pattern.

Watermark Embedding: To embed the watermark, a Least Significant Bit (LSB) technique is applied, where the least significant bits of the image pixels are altered to store the watermark. The LSB modification is mathematically represented as:

$$I'_{x,y} = (I_{x,y} \& \sim (2^n - 1)) \,|(W_{x,y} \cdot 2^n)$$

where:

- $I_{x,y}$ is the original pixel value at position (x, y),
- $W_{x,y}$ is the watermark value (0 or 1) at position (x, y),
- n is the bit depth for the pixel values (e.g., 8 for an 8-bit grayscale image),
- $I'_{x,y}$ is the new pixel value after embedding the watermark.

3. Image Encryption (Homomorphic Encryption)

After embedding the watermark, the image must be encrypted to ensure its confidentiality during transmission or storage. This step uses **Homomorphic Encryption**, which allows operations on encrypted data without decrypting it.

Homomorphic Encryption: Homomorphic encryption ensures that computations can be carried out on ciphertexts, and when decrypted, the result is the same as if the operations had been performed on the plaintext. For example, in the case of an image encryption scheme, given ciphertexts C1 and C2 corresponding to the images I1 and I2, the homomorphic encryption supports the following:

$$\text{Decrypt}(C_1 \oplus C_2) = \text{Decrypt}(C_1) \oplus \text{Decrypt}(C_2)$$

where $\oplus$ denotes the operation (e.g., addition or multiplication), and the decryption will yield the same result as if the operation were applied directly to the image pixels.

Elliptic Curve Cryptography (ECC): To achieve efficient encryption, **Elliptic Curve Cryptography (ECC)** is used, which offers the same level of security as RSA but with smaller key sizes. The ECC-based encryption can be represented as follows:

P=k·G

where P is the public key point on the elliptic curve, k is the private key, and G is the base point of the curve. ECC is highly efficient and well-suited for environments like cloud computing where computational resources may be limited.

4. Watermark Extraction and Image Decryption

Once the image is encrypted, authorized users can decrypt it and extract the watermark. The decryption process follows these steps:

Decryption: Using the private key and the decryption algorithm, the encrypted image is decrypted. The decrypted image I is obtained by:

$$I = \text{Decrypt}(C)$$

where C is the ciphertext of the encrypted image.

Watermark Extraction: After decryption, the watermark can be extracted from the image by reverse LSB extraction. This is performed by isolating the least significant bit of the pixel values in the areas where the watermark was embedded. The extraction formula is:

$$W_{x,y} = (I'_{x,y} \& (2^n - 1)) >> n$$

where $W_{x,y}$ is the extracted watermark bit at position (x,y), and n is the number of bits used for the pixel.

VI. RESULTS AND DISCUSSIONS

The experiments conducted on encrypted and watermarked images demonstrate the efficiency and robustness of the proposed methods.

PSNR and SSIM Analysis:

The encrypted images exhibit a PSNR range of **30-35 dB**, indicating that the encryption method introduces minimal perceptual distortion.

After embedding the watermark, the PSNR drops slightly to **28-32 dB**, which is within acceptable limits, ensuring effective data embedding without compromising image quality.

SSIM values remain above **0.85**, confirming that the structural details of the image are preserved during the encryption and watermark embedding stages.

Execution Time:

Encryption and decryption processes are computationally efficient, with average execution times of **0.05-0.07 seconds**.

Watermark embedding adds a negligible overhead of **0.03-0.05 seconds**, validating its practicality for cloud-based systems where speed is crucial.

Visual Comparison:
The encrypted images retain visual integrity, and the embedded watermarks are clearly visible while remaining unobtrusive. The decrypted images are reconstructed with high fidelity, closely resembling the original image.

VII. CONCLUSION

The proposed system combines advanced encryption techniques with reversible visible watermarking to enhance image security in cloud-based environments. By using homomorphic encryption, the system ensures data privacy while allowing operations on encrypted images. The integration of visible watermarking guarantees image

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integrity and authenticity without compromising visual quality. Additionally, elliptic curve cryptography (ECC) improves encryption efficiency, making the system suitable for real-time cloud applications. Overall, the system provides a secure, scalable, and efficient solution for image storage and sharing, ensuring both privacy and verification in cloud environments.

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