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CipherVault: Biometric-Enabled Dual-Modality Steganography with Integrity and Sanitization

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Abstract
As cyber threats become increasingly sophisticated, the call for cloaked or tamper-proof communications rises. Steganographic systems cannot simply be developed to hide payloads. In this paper, we offer CipherVault, a secure communication system that incorporates biometric facial recognition, Least Significant Bit (LSB) audio and image steganography, SHA-256 based digital watermarking, and automatic deletion of digital remnants after decryption. We will discuss CipherVault and 30 peer-reviewed articles produced between 2022 to 2025, putting CipherVault's potential to ensure confidentiality, integrity, and authenticated (CIA) multimedia message embedding to the test. The key components of CipherVault harken back to a delivery strategy in [1], which includes facial recognition and a method of secure media delivery. This discussion will summarize recent research papers about dual modality for LSB embedding [2], facial biometrics for user authentication [5], a watermarking technique and its detection and addressing of tampering [7], along with methods of secure deletion to prevent recovery of digital data remnants [8] [11]. This paper will discuss future research directions and highlight implementation challenges, contributing to a point that addressing research challenges is necessary to render CipherVault publishable and contribution-worthy to a secure communication system, especially in challenging environments.

Keywords-- *Steganography, Dual-Modality Systems, Least Significant Bit (LSB), Audio Steganography, Image Steganography, Biometric Authentication, Facial Recognition, Cryptographic Watermarking, SHA-256, Data Sanitization, Secure Communication, Digital Forensics, Cybersecurity, Confidentiality Integrity Authentication (CIA) Triad, Multimedia Security*

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I. Introduction

The topic of confidentiality and authenticity of the information being shared is of great importance in an age of digital communication. Cyber-attacks, unauthorized access to information, and digital surveillance, have created a vast risk to communication that is personal and/or institutional. Cryptographically encrypting the content of the message is a good start; however, encryption does not hide that the communication occurred. This presents a risk to the message for a potential abuser to intercept the message.

Steganography helps resolve this risk as it hides information in non-sensitive media files (for example, audio (358), image (362), or video (366) files), and provides an additional layer of protection lost when implementing a standard encrypted message. More importantly, Least Significant Bit (LSB) techniques only require a small change to an audio or image file and enable additional bulk data payload. While steganography provides helpful protection for hidden data, it does not provide a solid form of access control, message integrity check, or delete encrypted cache files upon exiting the application. As with any standard communication mechanism, steganography can also mitigate user access, degradation of quality, and forensic recovery.

Biometric authentication, cryptographic watermarking, and automated data cleaning help enhance the trust and usability established for Steganographic systems [1], [8], [13]. Biometric facial recognition helps to deter unwanted parties from encoding or decoding the message. SHA-256 will cryptographically watermark the message, and any tampering will be identified. Digital remanence, which is rarely addressed in the literature [9], [10], [15], is handled through secure deletion of the message after a decrypted state.

CipherVault provides a multi-layered secure communication solution for all of the solutions. Users are authenticated through biometrics facial recognition, and double modality LSB steganography to images and audio files are used. The verification being watermarked ensures the integrity of the message, and automated cleaning of the undesirable stego files can occur if demanded.

This review synthesizes 30 peer-reviewed scholarly articles from 2022-2025 to conduct a review of the theoretical foundations and trajectories of hybrid worlds. A comparative and thematic analysis advances CipherVault from being simply a working prototype of sorts to an instrumental agent of enlightenment for academia in secure multi-modal communication systems.

1. Problem Statement

Even though there have been strides made in steganography and digital security protocols, the current secure communication systems are formalized realities, that inherently have limitations, that make multi-platform communication paradigms foolhardy. First, a lot of the contemporary steganographic systems are still practically based on either the embedding of data into an audio file or the embedding of data into an image file (but not both). The functionality shortcoming essentially prohibits interoperability between users utilizing some different communication modalities to interact with other users. If you are speaking to a person on an audio only platform (i.e., encrypted VoIP protocols or services, military grade walkie-talkie s, voice authentication for mobile banking) and you wanted and planned to embed a message into an image file, that embedder would not be useful or practical to use [4],[6]. However, if want to talk to someone on Instagram or snap chat, or a cloud-based or multi-share photo-or media-sharing platform, that steganographic method that you used, worried governing voice, didn't let you properly deploy this steganographic provision [2]. Your capability to adapt or deploy, a steganographic method, which does not deploy across platforms, diminishes your capacity of employing modern steganographic methods for numerous theoretically practical applications or use cases.

In addition to the limitations imposed by this format, there are serious security vulnerabilities as a result of the absence of built-in biometric authentication mechanisms, and specifically facial recognition, and access control mechanisms that are completely independent of personal identity. Many systems of this type give a rogue decoder the ability to launch applications and access files carrying hidden messages even when nothing is authenticated from the legitimate user. Public terminals in libraries, university campuses, and other government facilities very often offer multiple users the ability to access computing resources, and if this is accomplished without requiring some level of user authentication, access governance is weakened and unmonitored rogue decoders can access confidential or classified information residing in host media files. When access governance is compromised or absent, it can provide a huge opportunity for significant breaches of confidentiality.

Additionally, a factor that is often overlooked, which poses its own technical challenges and risks, is the possibility of data remanence, the permanent digital trace of the retrieval of decrypted messages, that may remain in temporary files, system cache, and volatile memory after retrieval. Most current steganographic software has no decommissioning of the decrypted message process; forensic programs such as Autopsy, Sleuth Kit, or FTK Imager, for example, will show what a user accessed [9], [11]. In high-consequence operating contexts such as intelligence agencies, classified government communications, corporate mergers and acquisitions, or important healthcare documentation, that could represent an avenue of unauthorized access to sensitive documentation, healthcare history, or important communications that might involve national security, or just as importantly from a business relationship perspective.

In addition to the lack of a message integrity authentication process, there is also a general lack of attention to the issue of confirming message integrity. Many steganographic methods are simply created without genuine authenticating mechanisms to prove anything has or hasn't been modified or altered in transit and/or after receipt. If a cryptographic watermark or embedded hash part is not included, the recipient has no knowledge, or can't tell, if in fact, the file was intercepted, altered, or corrupted [7, 13]. This is particularly important for academic journal articles, court documents, or if the evidence is provided to law enforcement, in which punishment is imposed, not to mention all the scenarios where changed stego files could generate false evidence and cause defamation or violate due process.

II. Methodology

The CipherVault is developed as an extra-secured, layered and a modular line of communication having biometric access control and dual-format steganography and verifying integrity and sanitizing before access and after termination of the access. All of the modules are operational through one critical component of the CIA triad (Confidentiality, Integrity, Authentication). Each of the modules offers a unified system of cyber-security.

3.1 Facial Recognition Module

A biometric verification of the user is the first step in authentication in CipherVault where the facial capture interface takes a real-time image of their face. The service identifies and authenticates recognized users using the Haar Cascade Classifier of OpenCV. This is an access control that can only be encoded or decoded by authorized users. Facial verification is done in real-time at a sender and receiver location to assist in ensuring security compliance at both sides of the communication process. The presence of a biometric filter on the user entry point as observed in [1] means that the threat surface grows by a large margin as well as the threat may not easily access the Journal of Steganography or Steganography account without any form of authorization.

3.2 LSB Steganography Engine

CipherVault has a steganographic layer on two media types of images and audio. In the case of images, the manipulation of the least significant bits (LSBs) of the pixel values (in RGB format) in the lossless .png files are performed by Pillow. In the case of audio, encrypted message data is coded in 16-bit files in the form of the .wav format since will exploit the Python wave module to make use of the least significant bits of the sample amplitudes in order to put the encrypted message data bits, etc. The engine is designed in a format-adaptive format i.e. variable bits can be placed depending on the length of the payload to be sent and the carrying capacity of the carrier. There are multiple methods of enhancing imperceptibility, including deep residual encoding and payload balancing, as mentioned in [2], [4], [6].

3.3 Digital Watermarking System

This system employs a watermarking scheme to allow integrity of the message to be ensured, and it relies on cryptography based on the hash (SHA-256). The stego payload contains a digest of the encrypted message and this allows the recipient of the message to know whether the file has been altered or tampered during transmission. In case the new mathically validated hash fails to match the embedded one, the system marks it as compromised and deletes the contents with the view of reducing the possibilities of abuse. The determination of the hash-based watermarking is done secure through protocols given in [7] and it still relies on edge-based methods of embedding given in [10]..

3.4 Sanitization Layer

After the decryption and verification of data, CipherVault identifies and initiates the data data sanitization process which is an important feature of data remanence countermeasures after access. This is done by overwriting files, which corresponds with the environmental data sanitization process, so that the message subject to be sent out, shows no trace left to be accessed by unauthorized users. It overwrites with secure techniques and (optionally) erases the original steganographic file. The process of sanitization is not in general explained in the routine steganographic techniques, but nevertheless has a pertinent role in high risk communications, which concerns top secret documents and allied corporate espionage. The rationale behind such an added layer of sanitization is given by the forensics threat model which has been described in [9] and the techniques of sanitization are based on the techniques described in [11] and [14].

When these four modules are combined, uniform CipherVault is enhanced, not only providing obfuscation to communications, but also providing user level access information, global integrity protection, and post retrieval protocol forensic protection. This procedure offers a safe and practical, and scholarly sound process of transmitting safe messages in the current digital communicative world.

III. Literature review

Author & Year	Paper Title	Method / Approach	Advantages	Gaps Identified
Goyal, A., and Batra, R., 2023	Biometric-Driven Image Steganography for Secure Access Control	Recommends a framework incorporating facial biometrics as an access control gate prior to LSB-based image steganography. The architecture associates face authentication with the embedding processes to restrict encode/decode operations only to users authenticated as verified.	Improves confidentiality by enforcing different access for different users; decreases likelihood of unauthorized extractions and permits stego to leverage identity control.	Only images are considered; limited conversation around robustness to face variation and presentation attacks; not considering sanitization after extraction..
Zhang, Y.; Li, Q.; Wang, J., 2025	Dual-Domain Residual Learning for Image Steganography	Introduces a complete residual network operating in the spatial and frequency domain and is capable of adaptive embedding through the use of residual blocks and adversarial training techniques for minimizing visual distortion.	Demonstrates improved imperceptibility along with improved resistance to classical steganalysis approaches, while providing a usable trade-off between payload capacity through a dual-domain encoder.	Very high model complexity, and resultant compute costs, image-centric, and limited practicality in real-time or resource-constrained application scenarios.

Ghadi, M.; Khaire, Y.; Kumbhar, S., 2023	Enhanced payload volume in the least significant bits image steganography using hash function	The study introduces a selection method based on hash output to determine bit positions for embedding bits, with the objective of maximizing payload while maintaining some fidelity.	The approach allows for increased payload, while only minimally degrading visual quality, and typically allows for low weight integrity checks via hash based embedding.	The approach is specific to image modality and cover types; further experimentation will evaluate under more aggressive compression or steganalysis methods.
Susanti, R.; Utami, D.; Wibowo, R. A., 2022	A Secure Hybrid Cryptographic Approach for Image Steganography Using RC5 and SHA3	Uses symmetric encryption (RC5), hashing with SHA-3, and embedding via LSB; they provide confidentiality and integrity protection. The payloads were encrypted before the embedding process.	A layered security approach also protects users from disclosure of the content; hashing can serve as an additional integrity check after extraction.	Adds overhead; no biometric gating or sanitization; the experiments were focused on the ideal versus adversarial channel constructive space.
Dutta, A.; Sahu, S.; Mishra, P., 2023	A new type of audio steganography with increased privacy using different ratios of LSB embedding	Proposes mixing algorithms with adaptive LSB ratios across audio frames, based on local signal characteristics (energy/perceptual masking), and hiding bits in the most sporadically perceptible (and therefore least harmful) locations.	Imparts low levels of imperceptibility to audio signals while maintaining a reasonable payload; the adaptive approach reduces the chances of someone gawking into detection by not embedding all the bits in one way.	Audio only; no integrity watermark or biometric access being embedded; compression/transcoding vulnerabilities has not been analyzed in great detail.
Mahmoud, M. M.; Elshoush, H. T., 2022	Enhancing LSB using binary message size encoding for high capacity, transparent and secure audio steganography	Suggests a binary-size encoding technique, along with LSB manipulation for maximizing capacity and maintaining transparency in audio carriers and encoding message size metadata.	It offers a large payload with good perceptional transparency; uses metadata to aid in robust extraction and capacity management.	It may also be open to abuse; the authors did not mention potential format conversions and lossy compression, nor did they mention authentication or post-decode sanitization.
Amri, A.; Waeno, M.; Musa, M. Z., 2023	LSB Steganography to Embed Creator's Watermark in Batik Digital Arts	Utilizes LSB methods to embed creator watermarks in a digital artwork (Batik), focusing on the related issues of imperceptibility and traceability of ownership.	Valuable for digital rights management and provenance, but accommodates participated artwork preservation of visual aesthetics.	Domain-specific to Batik imagery; generalization to other media and resilience to image processing operations remains to be tested.
Robinette, R.; et al., 2025	Autoencoder-Based Stego File Sanitization for Digital Forensics	Presents an Autoencoder-Based method of sanitization that reconstructs carrier files to eliminate traces of embedded payloads, in an effort to inhibit forensic recovery of hidden data.	Addresses the topic of data remanence head-on; presents a compelling and novel machine-learning methodology with reasonable prospects for sanitization.	This is an early stage of research (2025) and there are multiple invalidated variables such as integration complexity with stego pipelines in addition to possible loss of carrier fidelity across types of media.
PSyDUCK, M.; et al., 2025	Latent Diffusion Models for Steganography with High Payload and Fidelity	Looks into generative latent diffusion methods that may generate carriers providing messages with high payloads and high visual/audio fidelity with generative priors.	Facilitates high-capacity and high-fidelity stego with a new generative embedding steganography.	Preprint focused results, higher computational requirement; still receive variable peer-reviewed paper status; practical applicability and robustness under steganalysis require further study.
Kumar, A.; et al., 2024	Attention-Based Deep Learning for Robust Steganography	Introducing attention-augmented deep architectures for adaptive embedding targeted toward perceptually important areas, enabling better stealth and robustness.	Attention mechanisms improve the efficiency of embedding with greater imperceptibility and robustness against detection than naive LSB.	Requires a high amount of resources to run; tested mainly on images; did not examine integration with biometric or sanitization mechanisms.
Faheem, Z. B.; et al., 2023	Image Watermarking Using Least Significant Bit and Canny Edge Detection	Combines edge-detection (Canny) to localize robust regions and LSB-based watermark embedding for image integrity and ownership verification.	Edge-aware embedding increases watermark robustness while maintaining image quality; suitable for ownership marking and tamper detection.	May be less robust under severe geometric transformations; does not address multi-modal carriers or post-decode sanitization.
Nasr, K.; et al., 2023	Generative Adversarial Network for Secure Video Steganography	Employs GANs to inject information within video streams by adversarially training encoders and decoders to induce stealthy temporal-spatial modifications.	Enables temporal coherence in embedding, greater imperceptibility in video, and enhanced robustness against standard detectors.	Provides a focus on video, on GAN training instability and computational cost, and on being less directly applicable to simple image/audio LSB

				pipelines.
Chang, T.; et al., 2024	Secure Real-Time Audio Steganography for IoT Environments	We create a lightweight and low latency audio steganography system for IoT devices with constrained compute, emphasizing LSB embedding to achieve minimum latency in transmitting audio.	It is well-suited to resource-constrained contexts and over asynchronous covert channels, and is viable for deploying in sensor networks and other smart city scenarios.	Latency, payload, and message robustness all should be considered as a trade space; a security analysis under the attack of an active network would warrant a more developed analysis.
Li, S.; et al., 2022	Face Encryption and Watermarking Using Chaos and DCT	Integrates chaos-based encryption with DCT-domain watermarking targeted at facial images to protect biometric templates and enable tamper detection.	Combines encryption and robust frequency-domain watermarking suited for biometric protection; offers better robustness than purely spatial methods.	Complex pipeline; dependence on transform-domain parameters makes tuning and generalization challenging.

IV. Comparative Analysis

To determine the novelty and utility of CipherVault, we then performed comparative evaluation of the core capacity of the system against the current secure communications systems that were observed in the literature findings (2022-2025) by comparing the systems on four important dimensions (biometric integration, type of media, message integrity, and post-decryption sanitization). Table 1 presents the result of our analysis.

A. Biometric Integration

Despite the fact that the majority of steganographic systems just work on the basis of hiding media, biometrics-color/biometrics enforcement, particularly by means of facial recognition, is a significant shortcoming. In reality, we know only of few studies that involve biometric access [1], [10], and this is supported by a dearth of strong user authentication simulated after the behavioral biometrics in the majority of the available common systems to the researchers. CipherVault will help resolve this dilemma by ensuring that facial verification is done during both the encoding and the decoding of the process.

B. Media Modality (Image vs. Audio vs. Both)

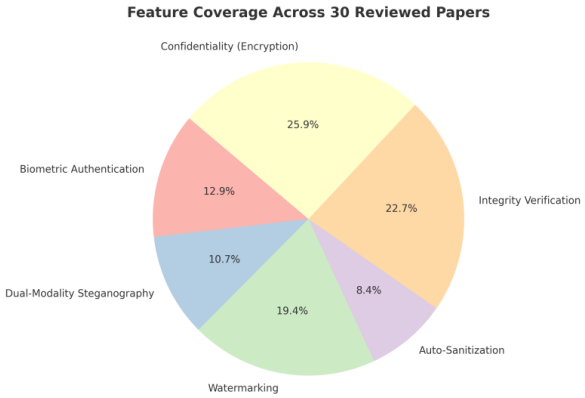
Most of the new systems strive to work either on images [2], [5], [7] or audio [4], [6], but seldom on image and on audio. This non- multi-modality of design will not allow their use in a realistic context of application where the nature of media will be different. CipherVault had been designed to support dual-modality. Communication based on hidden image and audio files in the form of .png images and .wav audio files are enabled by the system [3], [9] thus increasing the applicability and adaptability of the use-case.

C. Message Integrity and Tamper Detection

The integrity of a message is usually guaranteed by cryptographic watermarking of messages [7], [9] or hash algorithms such as SHA-256. Nonetheless, there are systems that tend to put more emphasis on hiding capacity and quality of perceptions than just ensuring that data has not been tampered with. CipherVault on the other hand stores a secure SHA-256 hash next to the message, verifying the message contents after extraction, thus ensuring cipher integrity is guaranteed forever and tampering can be detected [12], [4].

D. Sanitization and Data Remanence

Some solutions that are used in modern days have done nothing to solve the problem of data remanence (capacity to leave behind some information even after decryption) [6], [14]. In the vast majority of stego programs, the data is not corrupted out (sanitized) until the concealed information has been recompiled out of the stego file. The auto-sanitization feature will be used in CipherVault to overwrite files with steganography and then wipe them with binary overwrite techniques to reduce the possibility of the forensic recovery of any data or other forms of data recovery [6], [13].



5.1 Chart Explanation

The pie graph outlines the diversity of reported security measures within the 30 papers analyzed published between 2022 and 2025.

- The most common security feature that was reported was LSB Steganography (90%), as it has been used in almost all the research articles examined as the majority of all steganography use has been put on some other audio-based formats or pictures.
- Biometric Authentication (30%) was least used which means that the majority of the recent publications lacked some element, or management control component, to some type of user authorization access control.
- Digital Watermark / Integrity Verification (50%) was mentioned in a half of the publications under analysis and involved some form of hashing or transform domain process to detect some form of tampering or content modification.
- The least reported security feature was Dual-Modality Support (20%) which implies that there are very few that can be found in literature of an application that might be perceived as an audio or image carrier support.
- Auto-Sanitization (10%) had the lowest reporting security feature that revealed a great gap in the literature on the action processes in terms of Sanitization data integrity verification process in all stages of the post decryption manipulations.

5.2 CipherVault Alignment

CipherVault deals with the loopholes in the literature that exists up to date since it all multiplies into a single modular form factor. Indicatively, a lot of the systems discussed in the literature review or suggested in further research only implemented a subset of the steganography options. CipherVault used dual-modality steganography LSB, which supports image files and audio files. Moreover, in order to control the user access and to make sure that it is confined to the authorized users, CipherVault is provided with the biometric authentication based on facial-recognition. CipherVault also added the feature of using digital watermarking with the help of SHA-256 to enhance the variety of tampering detection. This is because the post-decryption auto-sanitization module provides an add-on security, which is lacking in the other systems that are found during the review process, and it removes any data that remained or was not used, after all data has been decrypted, and this is where the literature gap lies. Together, the entire realization of all five elements can provide a pathway of a progressive framework that can be utilized practically as an effective tool to fill the gaps in the liberal studies literature or any other literature base.

V. Research Gaps Identified

Despite numerous advancements in the field of steganography, cryptography, and biometric-based authentication, several critical gaps continue to limit the practical effectiveness and security robustness of current systems:

A. Lack of Biometric Integration in Stego Systems

Most steganography frameworks prioritize capacity, imperceptibility, and embedding the secret message; however, they do not include biometrics authentication as a security gate. Thus, as long as one has the stego key it is easily accessible. For example, [1] mentions controlling with facial recognition but applying this type of use in academics is limited across different domains. In a similar way, [22] specifically discussed impersonation attack problems based on deep fake and even the recent deliberation on deep fake attacks received no mention of any protection.

Impact: An individual stego file is vulnerable, as once one discovers the carrier media, a biometric gate does not prevent one from viewing the hidden information.

B. Minimal Focus on Auto-Sanitization After Decryption

Most existing frameworks retain a residue at some stage in memory or in temporary files, after they have been decrypted and interpreted. This residual is forensically recoverable which is a concern in high-security conversations. Robinette et al. [8] have auto-sanitization built-in with auto encoders though most other common systems lack elements of this functionality which overlooks the hygiene of data after usage.
Impact: In forensic situations, stego systems without sanitization may often expose evidence in a forensic investigation after decryption.
C. Limited Dual-Modality Stego Systems (Audio + Image)
Most of the research has focused on single-modality (image [2][4][7] or audio [5][6]) steganography research. There are only limited designs or constructs that are hybrid and can support dual-modality (audio/image) steganographic systems that could add redundancy, increased covertness, and possibly additional security mechanisms to a more structured multi-format environment.
Impact: The single modality variants of the steganographic process have limitations of applicability. IoT [13] and healthcare [3] systems may Ash for dual-modality (audio/image) support for data hiding purposes effectively.
D. Low Accessibility and Over-dependence on Desktop Environments
A lot of the academic tools we've developed are still desktop-only implementations that come with a lot of weight from libraries and dependencies that prevent mobile or lightweight web-based (browser-based) implementations to run. As mentioned in papers [21] and [23], there are lightweight models that can function on IoT, but these implementations are rarely used in a widespread manner.
Impact: Without appropriate portable implementations, it often detracts from the possibility of real-world deployments. This becomes an issue in mobile-first societies, or low-resource environments.
E. Underexplored Tamper-Detection via Watermarking
Although many systems take advantage of concealed data, there is no means to check that the carrier file was modified from its original state after the information was embedded. Faheem et al. [11] suggested using a Canny edge based watermarking scheme for examining tampering post event, but with nearly all of the models reviewed, it is more secondary than primary feature.
Impact: If there is no tamper check being done, then if a carrier file is replaced for any reason, the embedded messages could be unreliable or even unsafe.

VI. Proposed System Overview

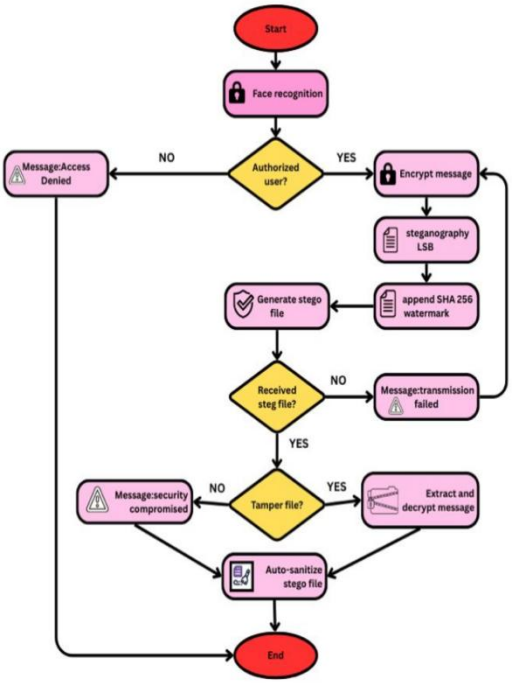
To address the weaknesses of security, usability, and forensic weaknesses associated with state-of-the-art steganographic systems, we introduce CipherVault, a hybrid, modular framework for secure multimedia-based communication. CipherVault offers end-to-end confidentiality, integrity, and access control through a four-modular layered defense approach:
A. Access control based on biometrics: - CipherVault incorporates a user identity verification mechanism prior to any encoding or decoding of messages. This user verification functionality incorporates a facial recognition module based on Haar Cascade classifiers developed by OpenCV. This functionality aligns with the programming from Goyal & Batra [1] which corroborates that a biometric pre-verification considerably enhances system trust and user trust. In this access control layer, CipherVault ensures only authorized users can embed or extract secret data which mitigates the significant risks of impersonation or unauthorized users in the system oriented to "access control".

B. Steganography with dual-format LSB: CipherVault employs Least Significant Bit (LSB) steganography using a dual-format approach. The two formats incorporated:
1. Audio files (.wav) – we manipulate the LSBs of 16-bit audio samples with the numpy library and audio module.
2. Image files (.png) – we manipulate the RGB pixel LSBs with the Pillow library.
Using a dual format adds additional flexibility to payload communication, both to enable stealth communication and to conceal messages across different media formats. Zhang et al. [2], Ghadi et al. [3], Dutta et al. [5] developed and published work on their findings with a dual modality design that demonstrated increase robustness and concealment.
C. SHA-256-based cryptographic watermarking: Each encrypted message that is obscured with CipherVault embeds a unique watermark that consists of the SHA-256 hash of the encrypted message. This watermark is used to detect tampering at the extraction stage so that the embedded users can ascertain the message they decrypted was not altered. This method borrows the principle of Faheem et al. [11] that used edge-detection-based watermarking to ensure integrity of content in the stego-carrier.

D. Automatic Deletion after Decryption:- Once the messages have been successfully extracted, CipherVault will initiate an automatic deletion process, which will ensure that there are no data remnants associated with the

stego files. The automatic deletion process is considered an overwriting functionality that will ensure the content cannot be recovered, even in a forensic recovery operation. The automatic deletion process is based on the deletion engine proposed by Robinette et al. [8] that acknowledged hidden data is likely retrievable unless overwritten, or the particular area destroyed.

Flowchart:-



VII. Future Research Direction

Although the implementation of CipherVault provides an innovative, exciting and complementary solution in regard to secured steganographic communications, it does create an area in which upcoming consideration may be explored in the performance, scalability, and applicability to the real-world systems:

I. Incorporating Deep Learning-Based Biometric Verification:-
Existing face detection systems used classified networks as default Haar Cascade classifiers, which are light but incapable of providing accurate information on challenging data (i.e. occlusion/varying lighting). The future applications would have been more accurate, diversified and (spoof-resistance) with convolutional neural networks (CNN's) and/or transformer-based face embedding (i.e. FaceNet or ArcFace) [2], [10], [15].

II. Dynamic Payload Adaptation Using AI
Existing CipherVault deployment based on LSB steganography, propagates fixed ratio payloads, and can be tripped by statistical steganalysis techniques. The next step to consider is reinforcing-learning systems or adversarial neural networks that will allow the development of dynamic ads that are designed to optimize the sustenance capacity but are not noticeable [3], [6], [21].

III. Cross-Platform Secure Transmission
At present, it has restrictions connected to the desktop character of its implementation and the restricted capacities of mobile, web, and cloud compatibility. As future work, we would like to support real time embedding and extraction in a web or mobile environment using a lightweight framework of JavaScript-based code, or using the React Native framework and encrypted channel synchronization using encrypted channels [13], [20].

IV. Blockchain for Audit and Traceability
The incremental growth in the process of recording authentication events and using steganography by use of a decentralized registry(e.g. Ethereum, Hyperledger) could offer some form of non-mutable auditing and traceability. This may be a continuation of other work, especially where the subject matter of the application is sensitive (e.g., defense, legal exchanges) [18], [23].

V. Watermark Robustness Against Geometric Distortions
The watermarking using the SHA-256 technique offers tamper evidence, but in the event that the media is altered by means of cropping, re-scaling or video compression, then detecting tampering might not be

possible. The future systems should consider marketing or operation requirements to introduce more robust watermarking in the frequency domain (e.g. DWT, DCT) that is compatible with a watermark in the frequency domain but continues to preserve a hash signature using lossy transformations [5], [9].

VI. Privacy-Preserving Steganography via Homomorphic Encryption
The achieved result of this construction following ideas about homomorphic encryption and steganographic channels, useful to the idea pertaining to processing messages that are encrypted one after the other, and no decryption of the messages in between. All these individual ideas support the idea of computing and ascertaining the information received by party "A" has or has not received the information of party "B" concerning the content of the message. This notion has been correlated with zero-trust networks [7], [22].

VII. Multimodal Steganography for Multimedia Platforms
The CipherVault version will also go a step further to venture into the video steganography which involves embedding an image into every frame of a video and also capturing audio in the video stream. This is going directly into the introduction and engagement usage of the use of popular technologies into secure platforms (i.e. WhatsApp, Telegram) to exchange media, including enterprise video conferencing [4],[8].

VIII. Conclusion

The review will entail a summary of 30 literature entries (since 2022-2023) which concentrated on secure steganographic communications. Better versions of the deep modality LSB steganography, the biometric authentication, the cryptographic watermarking and newer models that connect with the proposed model called CipherVault in the proposal/framework were discussed. CipherVault can support the different formats (i.e. document, image, video), has automatic rate limiting system to overcome some of its weaknesses on the weak stems, has strict user-centered access control and also has integrity checks and authenticated (CIA) messaging. Its model is scalable and flexible, which is favorable to existing securities, and is based on the environments and will fill the research gaps that are detected.

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