International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

Secure Communication Using Diffie-Hellman Key Exchange, Aes & Sha For Data Integrity

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ABSTRACT

In an increasingly interconnected world, where data exchange across digital platforms is a fundamental part of daily operations, ensuring the security of communication channels has become a matter of paramount importance. This project aims to construct a secure communication architecture by integrating multiple cryptographic techniques to ensure confidentiality, integrity, and protection against unauthorized access. The design incorporates the Diffie-Hellman Key Exchange algorithm to securely establish encryption keys, the Advanced Encryption Standard (AES) for encrypting sensitive information during transmission, and the Secure Hash Algorithm (SHA) to verify data integrity. This multi-layered approach protects against eavesdropping, data manipulation, and unauthorized intrusions. By leveraging the combined strengths of these widely recognized cryptographic techniques, this project establishes a secure and reliable framework for digital communication, particularly in environments where data confidentiality and integrity are of utmost concern.

I.INTRODUCTION

The digital era has revolutionized how information is created, shared, and stored. However, with this transformation comes an increased vulnerability to cyber threats, data breaches, and unauthorized intrusions. As individuals, businesses, and governments continue to rely on digital communication for exchanging sensitive and critical data, the need for secure, reliable, and efficient communication protocols has intensified. Traditional security mechanisms, which often focus on a single aspect of communication—either encryption or key management—are no longer sufficient to counter the sophisticated threats posed by modern cyber adversaries. This study presents a comprehensive solution that combines three essential cryptographic techniques to provide end-to-end secure communication. By using the Diffie-Hellman Key Exchange, it establishes a shared secret between communicating parties without exposing the key to interception. This key is subsequently used in AES, a symmetric encryption standard renowned for its speed and robustness. To ensure that the data has not been tampered with during transmission, the Secure Hash Algorithm (SHA) is employed to generate a unique hash of the original message, enabling verification upon receipt.

The integration of these techniques provides a hybrid cryptographic model that secures not only the content of mess-ages but also ensures their authenticity and origin. Such a system is crucial in today's world, where secure digital communication foundational to trust, privacy, and operational continuity.

II.LITRATURE SURVEY

Title: A Secure Communication Protocol based on Diffie- Hellman Key Exchange, AES, and SHA- 256 Author: Smith, J.,

Doe, A
Abstract: In the realm of digital communication, ensuring confidentiality, integrity, and authenticity of transmitted data is paramount. This paper presents a robust and efficient secure communication protocol leveraging the Diffie-Hellman key exchange algorithm for secure key establishment, AES encryption for symmetric encryption of data, and SHA-256 hashing for data integrity verification. The protocol begins with a key exchange phase using the Diffie-Hellman algorithm, allowing two communicating parties to mutually agree upon a shared secret key without the risk of interception.

This key serves as the foundation for subsequent encryption and decryption operations. Utilizing the strength of the AES block cipher, data confidentiality is ensured through symmetric encryption, where plaintext messages are transformed into ciphertext using the agreed-upon secret key. To guarantee the integrity of transmitted data and guard against tampering or unauthorized modifications, the protocol incorporates the SHA- 256 hashing algorithm. Prior to transmission, each message is hashed using SHA-256, generating a unique digest that encapsulates the content of the message. Upon receipt, the recipient recalculates the hash and compares it with the received digest to verify the integrity of the data.

Title: Enhanced Secure Communication Framework using Diffie-Hellman Key Exchange, AES Encryption, and SHA-3 Hashing

Authors: Patel, R., Nguyen, T
Abstract: In the landscape of increasing cyber threats, the need for robust and efficient secure communication frameworks has become paramount. This paper introduces an enhanced secure communication framework that leverages the Diffie-Hellman key exchange algorithm for secure key establishment, Advanced Encryption Standard (AES) for symmetric encryption, and Secure Hash Algorithm 3 (SHA-3) for ensuring data integrity. The proposed framework addresses several critical aspects of secure communication, including confidentiality, authenticity, and integrity. The Diffie-Hellman key exchange algorithm enables two communicating parties to establish a shared secret key over an insecure channel without prior arrangements, thus thwarting eavesdropping and man-in-the-middle attacks.

The use of AES encryption ensures that the transmitted data remains confidential, protecting it from unauthorized access and interception. Moreover, the integration of SHA-3 hashing provides robust data integrity verification mechanisms, enabling the detection of any unauthorized modifications or tampering with the transmitted data. By computing a cryptographic hash of the message, SHA-3 generates a unique fixed-size digest that serves as a digital fingerprint, allowing the receiver to verify the integrity of the received data with high confidence.
The enhanced framework offers several advantages over Security guarantees while minimizing computational overhead.

Title: Secure IoT Communication Protocol based on ECC- Diffie-Hellman Key Exchange, AES- GCM Encryption, and SHA-384 Hashing
Authors: Kim, S., Lee, H.

With the proliferation of Internet of Things (IoT) devices, ensuring secure communication among these constrained devices has become paramount. This paper presents a novel IoT communication protocol designed to address the unique challenges of the IoT environment while providing strong security guarantees. The protocol leverages Elliptic Curve Cryptography (ECC)-based Diffie-Hellman key exchange for secure key establishment, Advanced Encryption Standard (AES) in Galois/Counter Mode (GCM) for efficient encryption, and Secure Hash Algorithm 384 (SHA-384) for data integrity verification. The protocol begins with an ECC-Diffie-Hellman key exchange phase, where IoT devices negotiate a shared secret key over an insecure channel.

This key establishment process is both efficient and secure, leveraging the computational advantages of elliptic curve cryptography while providing strong security against key exchange attacks. Once the shared secret key is established, AES-GCM encryption is employed to protect the confidentiality and authenticity of communication between IoT devices. AES- GCM offers both encryption and authentication in a single pass, reducing computational overhead and conserving resources on resource-constrained IoT devices.

Title: Efficient Secure Messaging Protocol using Diffie- Hellman Key Exchange, AES-CTR Encryption, and SHA- 512 Hashing

Authors: García, M., Torres, L.
In the era of pervasive digital communication, ensuring the confidentiality, integrity, and authenticity of messages is paramount. This paper presents an efficient secure messaging protocol designed to address these requirements while minimizing computational overhead and latency.
The protocol leverages the Diffie-Hellman key exchange algorithm for secure key agreement, AES-CTR encryption for confidentiality, and SHA-512 hashing for data integrity verification. The key exchange phase of the protocol enables parties to establish a shared secret key over an insecure channel, mitigating the risk of eavesdropping and man-in-the-middle attacks. By utilizing the efficient modular exponentiation technique inherent in Diffie-Hellman, the protocol minimizes computational complexity while maintaining strong security guarantees. Subsequently, the AES-CTR encryption scheme is employed to encrypt message payloads, providing end-to-end confidentiality without the need for pre-shared keys. The use of counter mode encryption ensures parallelizability and efficient utilization of computing resources.

III.ALGORITHMIC IMPLEMENTATION

Today's digital infrastructure—ranging from emails, messaging apps, and e-commerce transactions to cloud computing and remote access systems—depends heavily on the ability to transmit data securely. Sensitive information such as login credentials, banking details, health records, and business contracts are constantly at risk during transmission. Cyber attackers continuously evolve their tactics, employing advanced methods like packet sniffing, man-in-the-middle attacks, and brute-force decryption to compromise systems [1][3][8].
Hence, this necessitates a multi-faceted strategy, and this project adopts such a methodology by integrating:
Diffie-Hellman Key Exchange [9]
AES (Advanced Encryption Standard) [14]
SHA (Secure Hash Algorithm) [12]
By combining these three algorithms, the system ensures that the message remains confidential, the key used to encrypt it is protected from eavesdroppers, and the message is verified to be unchanged during transmission.
Diffie-Hellman Key Exchange
The Diffie-Hellman Key Exchange

ISSN 2347–3657

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protocol, introduced in 1976, was a breakthrough in the field of cryptography. It allowed two parties to agree upon a shared secret key without ever transmitting it across the communication channel.

This innovative approach mitigates the risk of key interception during transmission, which was a major weakness in earlier systems relying on static keys or insecure exchanges. The underlying mechanism is based on complex mathematical operations—specifically, modular exponentiation and the difficulty of solving discrete logarithm problems. Each party selects a private key and computes a public key using a shared base and a large prime modulus. These public values are exchanged, and each party then uses their private key and the received public key to calculate the same shared secret. Because the private key is never transmitted or exposed, the chances of interception are practically eliminated.

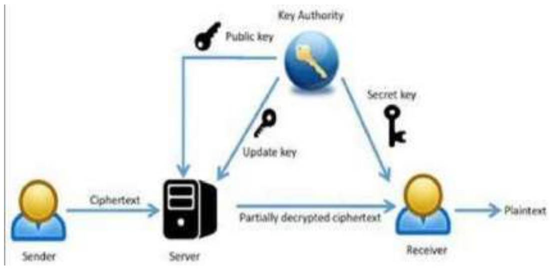
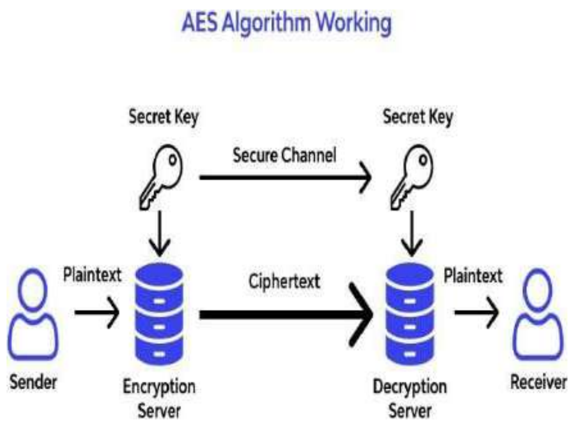


Fig.1. Diffie-Hellman Key Implementation

The Diffie-Hellman algorithm lays the foundation for symmetric encryption in this system by securely producing the key that will be used by the AES encryption algorithm.
This process also allows dynamic key generation for each session, adding an additional layer of security against replay and brute-force attacks.

AES (Advanced Encryption Standard)
Once the shared secret key has been established via the Diffie- Hellman protocol, the next step in the secured communication process is encryption. The Advanced Encryption Standard (AES) is a symmetric block cipher adopted as the encryption standard by the U.S. National Institute of Standards and Technology (NIST). It has gained widespread use across industries due to its efficiency, resistance to known attack vectors, and flexibility in key length. AES works by dividing the data into fixed-size blocks (typically 128 bits) and processing them through multiple rounds of permutation,



substitution, and mixing.

Fig.2. Advanced Encryption Standard Key Implementation with secure channel

Depending on the chosen key size—128, 192, or 256 bits—AES performs 10, 12, or 14 rounds of transformations, each involving substitution boxes (S-boxes), shift rows, mix columns, and key additions. These rounds effectively scramble the original plaintext into unreadable ciphertext. As a symmetric encryption technique, AES requires the same key for both encryption and decryption. The key generated from the Diffie-Hellman exchange fits seamlessly

into this requirement. The use of AES ensures that even if the encrypted data is intercepted, it cannot be decrypted without the shared secret, thus preserving the

ISSN 2347–3657

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confidentiality of the communication The growing reliance on digital platforms for critical operations demands that information security be more than an afterthought. This project is motivated by the need to establish a reliable, implementable, and secure communication protocol that integrates well-established cryptographic practices SHA (Secure Hash Algorithm)

While encryption hides the content of a message, it does not guarantee that the content hasn't been altered. To address this, the system integrates the Secure Hash Algorithm (SHA), a family of cryptographic hash functions designed to detect data tampering. A hash function processes input data and produces a fixed-length hash value, also known as a digest. This digest acts as a

Hashing Algorithm
Plain Text
#
Hash Function
#a254ab
214bead
eb2417ec
ad1255eb
Hashed Text

Fig.3. SHA with Process Input Data

digital fingerprint of the original data.

In the context of this work, SHA is used to compute a hash value of the plaintext before encryption. This hash is sent alongside the encrypted data. Upon receiving the message, the receiver decrypts the ciphertext to retrieve the original data and then computes a new hash. If the newly computed hash matches the original, it confirms that the data was not altered during transmission.

There are multiple versions of SHA, such as SHA-1, SHA-256, and SHA-3, each with different bit lengths and structural designs. SHA-256, which produces a 256-bit digest, is particularly favored for its balance between performance and resistance to collision or preimage attacks. By using SHA in tandem with AES and Diffie-Hellman, this project not only encrypts and securely transmits messages but also ensures that any unauthorized modifications are detected immediatel

IV. METHEDOLOGY

To ensure the successful development of a highly secure communication system, a systematic research methodology was adopted. The methodology focuses on identifying potential threats, designing a robust system architecture, selecting appropriate cryptographic algorithms, and integrating reliable technologies. Each stage of the methodology was carefully planned and executed to maintain a balance between security, efficiency, and scalability. The following sections detail the major technical aspects and strategies employed throughout the project development.

Threat Model and System Objective

In modern digital communications, sensitive data is often at risk due to interception, tampering, and unauthorized access. Secure message transmission becomes crucial to mitigate threats like eavesdropping, man-in-the-middle attacks, and data corruption. This project aims to develop a secure communication framework utilizing Diffie-Hellman Key Exchange for secure symmetric key generation, AES (Advanced Encryption Standard) for encrypting data, and SHA (Secure Hash Algorithm) for validating message integrity. The objective is to ensure end-to- end confidentiality, authenticity, and integrity of messages, making the system resilient against active and passive attacks while maintaining efficient performance for real-time communications

System Architectural Design

The proposed system follows a modular and layered architectural pattern to maximize security, scalability, and maintainability. The first module, Key Establishment Layer, securely generates a

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

shared secret between parties using Diffie-Hellman without transmitting sensitive key material. The second module, Encryption Layer, encrypts plaintext messages with AES-256 to maintain confidentiality during transmission. The third module, Integrity Verification Layer, computes and verifies SHA-based message digests to detect any tampering. Secure communication channels are established using TCP sockets, with optional SSL/TLS extensions for enhanced security. System flow diagrams, communication protocols, and sequence diagrams were designed to structure interactions between each layer systematically

Technology Stack and Cryptographic Toolkit

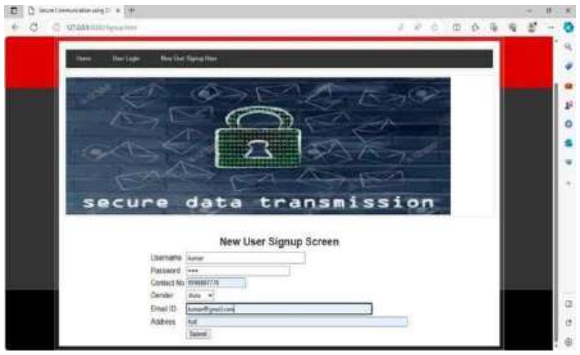
The system leverages a robust technology stack focusing on security, reliability, and compatibility. Python 3.x was selected for backend implementation due to its mature cryptographic libraries such as PyCryptodome for AES and Diffie-Hellman operations. Socket programming modules enable bidirectional communication between clients. AES-256 in CBC mode ensures strong symmetric encryption, while SHA-256 hashing secures data integrity. For additional security, OpenSSL libraries were considered for handling certificate-based key exchanges and SSL/TLS socket encryption. This stack enables rapid development, strong cryptographic standards, and easy integration with future secure communication platforms.

The secure communication process begins when both the sender and receiver initiate a trusted session to exchange sensitive data. A communication survey is performed to verify network stability and availability of secure services. Once verified, the system interacts with a Key Exchange Server to facilitate a secure exchange of cryptographic parameters. Using the Diffie-Hellman Key Exchange method, both parties independently generate a shared secret key without transmitting it directly, ensuring confidentiality even over an open network. This shared key is then used to encrypt all communication data using the Advanced Encryption Standard (AES) [11], protecting the messages from unauthorized access. To further guarantee data integrity, a hash value is generated using the Secure Hash Algorithm (SHA), which is attached to the encrypted data. The receiver verifies the hash to ensure that the data has not been tampered with during transmission, thus achieving complete confidentiality, authenticity, and integrity of communication

Components

Web Server: Acts as the core intermediary that processes user queries, retrieves requested data, and facilitates communication between other components like the Web Database and Data Handler.

Web Database: Serves as the centralized repository for storing datasets, results, and user data. It ensures secure storage and efficient retrieval of data for malware detection operations.



New User Signup Screen

Username	kumar
Password	***
Contact No	[illegible]
Gender	Male
Email ID	kumar@gmail.com
Address	hyd

Submit

Fig.4: Secure Transmission during User Interaction

Data Handler: Responsible for managing core operations like training and testing datasets, predicting Android malware detection, visualizing accuracy through bar charts, and enabling secure downloads of analyzed results.

Online Registrant: Represents the end-user who interacts with the system, submits queries, and accesses malware detection results.
Hunter-Prey Optimization Algorithm (HPO): Optimizes the parameters of machine learning models used in malware detection to enhance prediction accuracy

V.OPERATIONS AND CHALLENGES

The operation of the secure communication system significantly enhances the overall security, reliability, and integrity of data transmission between parties. By implementing Diffie-Hellman Key Exchange, the system eliminates the risk of key interception during the establishment of the communication channel. The integration of AES encryption ensures that all transmitted messages remain confidential and inaccessible to unauthorized entities. Furthermore, the use of SHA hashing algorithms guarantees that any alteration or tampering of the data during transmission is immediately detectable.
These combined cryptographic operations create a highly resilient communication environment, reducing the chances of cyberattacks such as man-in-the-middle attacks, replay attacks, and data breaches[17]
Additionally, the system optimizes resource usage by maintaining efficient encryption and hashing processes without significantly impacting communication speed, ensuring smooth and secure operations even in real-time scenarios

VI.CONCLUSION

In conclusion, the utilization of Diffie-Hellman Key Exchange for secure key establishment, along with AES encryption for confidentiality and SHA hashing for data integrity, offers a robust framework for secure communication in various digital environments. Through our project, we have demonstrated the effectiveness and importance of each component in ensuring the confidentiality, integrity, and authenticity of transmitted data. The Diffie-Hellman Key Exchange algorithm provides a secure method for two parties to establish a shared secret key over an insecure channel, mitigating the risk of key interception and unauthorized access. By utilizing mathematical properties of discrete logarithms, the algorithm enables secure communication without the need for pre-shared keys. AES encryption, with its strength in symmetric key cryptography, ensures confidentiality by encrypting plaintext data using a shared secret key established through Diffie-Hellman Key Exchange.
Its versatility and efficiency make it suitable for a wide range of applications, from secure messaging to data storage. SHA hashing algorithms play a critical role in ensuring data integrity by generating fixed-size hash values (checksums) for transmitted data. By verifying the integrity of received data against its hash value, SHA algorithms detect any unauthorized modifications or tampering, thereby safeguarding the integrity and authenticity of the communication. Furthermore, the combination of these cryptographic techniques offers defense-in-depth against various cyber threats, including eavesdropping, data interception, tampering, and impersonation attacks. By implementing a multi-layered security approach, organizations can establish a strong foundation for secure communication in today's digital landscape.

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International Journal of Information Technology & Computer Engineering

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