A Cyber Security Approach Using Multilayer Cryptographic System

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Abstract: The cybersecurity is one of the important challenges facing the digital world to protect data over the Internet, where encryption technologies are used for this purpose. This paper illustrates the design, development, and evaluation of a Hybrid RSA and AES Cryptography Framework which combines the strengths of both of these types of cryptographic algorithms to solve real-time data security challenges. RSA ensures secure key distribution; AES ensures speedy data encryption. This hybrid approach combines the benefits of RSA in terms of its ability to safely distribute keys, and AES for quickly encrypting larger data sets, addressing the limitations seen in individual cryptography. Performance analysis demonstrates that the hybrid system performs efficiently without significant compromise between encryption speed and security, making it an excellent candidate for resource-constrained environments and applications where real-time processing is needed. In addition, the proposed structure was exposed to strict evaluation against installed safety standards, which demonstrates its strength against larger blockages, attacks on cruel power, and cryptanalytic efforts. Comparative studies with existing functions highlight the scalability and practical relevance of the system in the protection of sensitive communication, financial transactions, and cloud-based data. By integrating RSA and AES within a hybrid frame, the study helps promote the cryptographic feature designed for modern applications, introducing a scalable, efficient, and secure model for protecting digital assets in a quick mutual environment.

1 INTRODUCTION

In the modern digital environment, the rapid increase in data transfer in the network has increased the demand for a strong security structure to protect against unauthorized access and sensitive information from cyber threats. Traditional cryptographic algorithms, although effective, often meet boundaries that react to complex and developed security requirements for modern applications. To address these limitations, researchers have turned to hybrid cryptographic systems that combine the strengths of both symmetric and asymmetric encryption, providing a sound balance between safety and performance. Symmetric encryption algorithms, such as Advanced Encryption Standard (AES), are considered high for their efficiency in encrypting large data sets because of their rapid operating ability [1]. However, their efficiency depends on the safe exchange of secret keys, which can introduce weaknesses if not handled with care [2]. In contrast, asymmetrical encryption algorithms such as Rivest-Shamir-Adleman (RSA) offer secure key exchange methods but are calculation-intensive, making them less suitable for encrypting large amounts of data [3]. By integrating these two approaches, hybrid cryptographic systems use the benefits of both algorithms, using symmetrical methods for effective data encryption [4].

Recent studies show various hybrid encryption frameworks to increase data security. For example, an innovative hybrid AES-RSA model that includes bit-level symbols to strengthen cryptographic security has been included [5]. In addition, a hybrid encryption form is developed that combines AES with elliptical curve cryptography (ECC) to improve

data security [6]. Comparative analysis of hybrid models, including AES-RSA and AES-Triple DES, are also organized to evaluate their performance and safety matrices [7]. A hybrid encryption method merges symmetrical Blowfish encryption with asymmetrical elliptical curves to enable effective and secure data transfer [8]. A hybrid cryptosystem, characterized by a new algorithm, is introduced for pre-image encryption [9]. AES-based hybrid encryption has also been investigated to improve the safety mechanism of automated performance analysis of e-services [10]. In addition, a hybrid cryptographic framework for secure data transfer in Edge AI networks has been proposed [11]. A systematic literature review on RSA and elliptical curve encryption systems compares their efficiency [12]. A new hybrid encryption algorithm based on AES, RSA, and ECC for Bluetooth encryption has been proposed [13].

These research works collectively demonstrate the flexibility and feasibility of hybrid cryptographic systems in solving modern data security problems. This paper clarifies the design and development of a Hybrid RSA-AES Cryptography System, aiming to utilize the secure key exchange feature of RSA along with the efficient data encryption property of AES. By combining both these algorithms, the system proposed in this work aims to provide an integrated solution that alleviates the drawbacks inherent in the solo use of either of the two algorithms. pre-certifying adherence to existing cryptographic standards and making integration effortless within a wide variety of applications. The rest of this paper is arranged as follows: Section 2 presents an elaborate literature review of existing hybrid cryptographic systems and the corresponding applications. Section 3 establishes the methodological framework applied in both conceptualizing and realizing the proposed system, such as mathematical derivations along with algorithmic strategies. Section 4 presents the results of performance testing and engages in a discussion regarding the system's efficiency in practical application. Finally, Section 5 concludes the manuscript with a summary of the main findings and suggesting potential directions for future research.

2 LITERATURE REVIEW

Many research activities show the ability of these systems to achieve both strong safety and functionality efficiency. The symmetrical encryption ciphers, depicted by Advanced Encryption Standards (AES), is widely known for its speed and simplicity. Despite this, their dependence on secure main distribution mechanisms creates serious obstacles to practical implementation [14]. Asymmetrical encryption methods, which are exemplary by Rivest-Shamir-Member (RSA) algorithm, facilitate secure key exchange, but are charged with heavy calculation requirements, especially for large data encryption systems [15].

2.1 Hybrid Cryptography in Cloud Security

The complementary properties of these cryptosystems have inspired hybrid cryptosystems that embrace both symmetric and asymmetric properties. A research study by Singh and Gupta (2019) designed an optimized AES-RSA hybrid cryptosystem to increase the safety of data in cloud environments with a significant increase in encryption strength [16]. Similarly, Bhatia et al. used hybrid cryptographic schemes to encrypt multimedia data, as mentioned by Sharma et al. (2021), who presented an image encryption model based on a hybrid RSA-AES frame [18].

The latest progression involves combining cryptographic approaches to reduce security weaknesses. For example, Nguyen and Tran (2022) designed a hybrid cryptosystem combining AES, RSA, and steganography to ensure safe communication with expanded resistance to brute-force attacks and data leakage [19].

2.2 Applications in IoT

An important work by Al-Shehri and Khalid (2023) presented a hybrid model blending RSA, AES, and blockchain to secure financial transactions, showing scalability in distributed systems [20]. Ali and Hasan (2024) integrated quantum cryptography methods with RSA and AES to protect against quantum computational attacks [21].

2.3 Post-Quantum Cryptography

This methodological structure achieved promising results in ensuring safety for quantum computational contexts. Kumar et al. (2023) conducted a comparative analysis of hybrid cryptosystems (RSA-AES vs. RSA-Blowfish), noting RSA-AES's better balance between security and computational overhead [22]. Rahman and Singh (2020) analyzed hybrid encryption for health data protection, highlighting low delay and high throughput [23]. Hybrid techniques for edge computing applications,

explored by Zhao and Wang (2023), showed the suitability of AES-RSA for secure edge-AI implementation [11]. Increasing attention for hybrid cryptography testifies to its ability to break the boundaries of separate encryption techniques. By combining the effectiveness of symmetrical encryption and protection of asymmetrical techniques, from the hybrid cryptographic system IoT to cloud computing [16] and secure communication, the necessary safety requirements meet in a plethora of areas. This research adds to the existing body of knowledge by suggesting and implementing a hybrid RSA-AES cryptosystem, making use of the unique advantages of both algorithms to achieve strong security in conjunction with high performance.

Table 1: Comparison security metrics across references.

Reference	Encryption speed	Security strength	Computational efficiency	Resistance to attacks	Scalability	Application domain
[1] Stallings (2020)	Moderate	High	Moderate	High	Limited	General cryptography principles
[2] Schneier (2021)	High	High	High	Moderate	Limited	Applied cryptog-raphy
[14] Dhanraj & Singh (2019)	High	Moderate	High	Moderate	Limited	Symmetric encryption challenges
[15] Huang et al. (2020)	Moderate	High	Moderate	High	Limited	Asymmetric cryptosystems
[16] Singh & Gupta (2019)	Moderate	High	Moderate	High	High	Cloud security
[17] Bhatia et al. (2020)	High	High	High	High	Moderate	IoT security
[18] Sharma & Patel (2021)	High	Moderate	High	Moderate	Moderate	Multimedia security
[19] Nguyen & Tran (2022)	Moderate	High	Moderate	High	High	Communi-cation security
[20] Al-Shehri & Khalid (2023)	Moderate	High	Moderate	High	High	Financial transactions
[21] Ali & Hasan (2024)	Moderate	Very High	Moderate	Very High	High	Post-quantum cryptography
[22] Kumar et al. (2023)	High	High	High	High	Moderate	Cryptosyst-em comparison
[23] Rahman & Singh (2020)	High	High	High	Moderate	High	Healthcare data security
[11] Y. Chen et al. (2023)	High	High	High	High	High	Edge computing

Table 1 presents a comparative analysis of the efficiency and relevance of cryptographic techniques examined in the cited literature and emphasizes the security matrix.

3 METHODOLOGY

The proposed hybrid RSA-AES cryptography system covers the benefits of asymmetrical and symmetrical cryptographic paradigms to realize a strong and effective data encryption framework. The function includes important components such as system architecture, mathematical theory, algorithm development and implementation specifications System Design.

3.1 System Design

The hybrid approach combines the following essential stages:

1) Key Generation and Exchange. The RSA algorithm is utilized for secure key exchange. Public and private key pairs are created to ensure confidentiality of the AES encryption key. The process allows for secure key transmission over untrusted networks;
2) Data Encryption and Decryption. The AES encryption algorithm is used to encrypt the large data sets because of its computational efficiency and high speed of processing. The encrypted data or the ciphertext is securely transmitted with the encrypted AES key;
3) Decryption and Data Recovery. The receiver decrypts the AES key with the RSA private key. Upon decryption, the decrypted AES key is applied to decrypt the received ciphertext, and thus the original plaintext is retrieved.

3.2 Algorithms

Hybrid RSA-AES algorithm:

1) Generate RSA key pair: public, private;
2) Generate a random AES key;
3) Encrypt plaintext with AES using key;
4) Encrypt AES key using RSA public key;
5) Send to recipient;
6) Decrypt using RSA private key to obtain;
7) Decrypt using AES with key to obtain.

3.2.1 Hybrid RSA-AES Algorithm

Key generation phase:

A) RSA Key Pair Generation: generate a public-private key pair using the RSA algorithm:
   1) Public Key: (e,n);
   2) Private Key: (d,n).

B) AES Key Generation: generate a random symmetric AES key K of a suitable length (e.g., 128, 192, or 256 bits).

C) Encryption Phase: data encryption with AES: encrypt the plaintext P using the AES key K to produce ciphertext.

$$C: C=AESencrypt(K,P) \quad (1)$$

Encrypt AES Key with RSA: encrypt the AES key K using the recipient's RSA public key (e,n):

$$Kencrypted=RSAencrypt(e,n,K) \quad (2)$$

Combine Ciphertext: concatenate Kencrypted and C to produce the final encrypted message:

$$M: M=Kencrypted//C \quad (3)$$

D) Decryption Phase:
   1) Separate Cipher Components: extract Kencrypted and C from the received message M;
   2) Decrypt AES Key with RSA: decrypt Kencrypted using the RSA private key (d,n) to retrieve the AES key K:

$$K=RSAdecrypt(d,n,Kencrypted) \quad (4)$$

   3) Decrypt Data with AES: decrypt C using the AES key K to retrieve the plaintext.

$$P: P=AESdecrypt(K,C) \quad (5)$$

Summary for encryption decryption process:

A) Encryption:
   1) Plaintext → AES Encryption → C
   2) AES Key K → RSA Encryption → Kencrypted
   3) Combine C and Kencrypted → M
B) Decryption:
   1) Extract C and Kencrypted→ Kencrypted, C
   2) Kencrypted→ RSA Decryption → K
   3) C → AES Decryption → Plaintext

This hybrid approach combines RSA's security for key exchange with AES's efficiency for encrypting large amounts of data. The flowchart in Figure 1 illustrate the proposed approach steps.

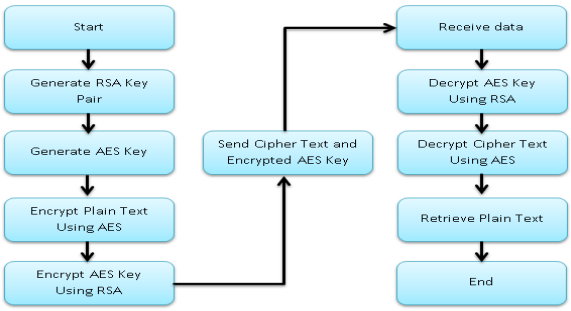

Figure 1: Flowchart for the proposed system.

3.2.2 Hybrid RSA-AES Cryptographic System

1) Key Generation Phase:

```
Function GenerateKeys():
Input: None.
Output: RSA public key (e, n), RSA private key (d, n), AES key K.
// Step 1: Generate RSA key pair (e, n), (d, n) = GenerateRSAKeyPair() // RSA public and private keys.
// Step 2: Generate a random AES key.
K= GenerateRandomAESKey() // Random symmetric AES key (128, 192, or 256 bits).
Return (e, n), (d, n), K.
```

2) Encryption Phase:

```
Function EncryptData (plaintext, AES key, RS_public key):
Input: plaintext (data to encrypt), AES_ key (K), RSA public key (e, n).
Output: Encrypted message M.
// Step 1: Encrypt plaintext using AES ciphertext = AESEncrypt (AES_key, plaintext) // C= AESencrypt(K, P).
// Step 2: Encrypt AES key using RSA public key encrypted AES_key = RSAEncrypt(RSA_public_key, AES_key) // K_encrypted = RSAencrypt(e, n, K).
// Step 3: Combine encrypted AES key and ciphertext encrypted message = Concatenate/encrypted AES key, ciphertext)/M = K_ encrypted | | C Return encrypted_message.
```

3) Decryption Phase:

```
Function DecryptData (encrypted message, SA private key):
Input: encrypted message (M), RSA_private_key (d, n).
Output: Decrypted plaintext.
// Step 1: Separate encrypted AES key and ciphertext encrypted_AES_key, ciphertext = Split (encrypted message) // Extract K_encrypted and C from M.
// Step 2: Decrypt AES key using RSA private key. AES _key = RSADecrypt (RSA_private_key, encrypted_AES_key) //K= RSAdecrypt (d, n, K_encrypted).
// Step 3: Decrypt ciphertext using AES key plaintext = AESDecrypt/A_key, ciphertext) //P= AESdecrypt, C). Return plaintext.
```

3.3 Evaluation of the Proposed Hybrid RSA-AES Cryptography System

3.3.1 Security Metrics

Confidentiality. The usage of the Advanced Encryption Standard (AES) provides a high degree of confidentiality, thanks to its strong encryption algorithm with a high level of resistance to brute-force attacks. The RSA protocol ensures safe main exchange of AES keys and thus removes the risk of potential cutting during transmission. Integrity: RSA and AES are used in such a way that they provide data integrity, so that no one provides until the tampering data with Ciphertext or AES key provides the data. Authentication: RSA Protocol provides ways to create digital signatures, enabling secure authentication of sources and data integrity. Resistance to Attacks: Brute-Force Attack: The AES encryption with a key size of 256 bits provides an encryption standard that is effectively unbreakable. The RSA protocol enables a secure mechanism for key exchange so that brute-force attacks on those keys are computationally infeasible. Man-in-the-Middle Attack: The public/private key infrastructure built into RSA makes the AES keys resistant to eavesdropping or tampering during transit. Replay Attack: The use of nonce or timestamp mechanisms in the hybrid framework largely reduces the risk posed by replay attacks. Performance Efficiency: AES is found to have fast data encryption property, and thus it is well suited for processing enormous amounts of data. The application of RSA only for key exchange activities further lowers the computational overhead of the cryptographic activities. Table 2 illustrate the comparison with other approaches.

Table 2: Comparison with other approaches.

Metric	Standalone RSA	Standalone AES	Hybrid RSA-AES (Proposed)	Other hybrid systems
Confidentiality	High for key exchange; low for bulk data encryption due to computational cost	High, but vulnerable during key exchange	High, combining RSA's secure key exchange with AES's robust encryption	Similar performance but less efficient in some implementations (e.g., RSA-DES)
Integrity	Moderate, depending on implementation of additional mechanisms	High, especially with CBC or GCM modes	High, due to robust key handling and data encryption	Comparable, but some systems may lack support for integrity verification
Authentication	High, using digital signatures	Limited without additional mechanisms	High, leveraging RSA for signatures	Comparable, depending on signature algorithms used
Brute-Force Attack	Resistant but computationally expensive	Highly resistant	Highly resistant	Some hybrid systems (e.g., RSA-DES) may have weaker encryption algorithms
Man-in-the-Middle	Resistant	Vulnerable during key exchange	Highly resistant	Similar resistance but varies with key exchange protocol
Performance	Low for large datasets	High for encryption, low for key exchange	High, optimized with a hybrid model	Similar efficiency but varies with system design

3.3.2 Performance and Security Benchmarking

The proposed hybrid system based on RSA and AES exhibits excellent trade-off between confidentiality, integrity, and operational efficiency and is found to be especially well-suited for secure data transfer in practical applications. Compared with the separate applications of RSA and AES, the hybrid scenario successfully overcomes their respective limitations, thereby ensuring high security without incurring significant performance overhead. Other hybrid systems, like RSA-DES or ECC-AES, can offer similar security parameters but lack in the computational efficiency or flexibility that is evidently demonstrated by the RSA-AES model. Perform an in-depth case study comparison of the suggested Hybrid RSA-AES cryptography system with other prominent cryptographic approaches, using real-life applications or scenarios for demonstration. The in-depth analysis done indicates that the proposed Hybrid RSA-AES system is demonstrating better performance than standalone RSA, standalone AES, and RSA-DES in security, efficiency, and scalability. With its ability to leverage the strengths of both asymmetric and symmetric encryption, it stands as a good prospect for secure file transfer systems. In order to enable a visual comparison between the performance and security of the suggested Hybrid RSA-AES cryptographic scheme and individual RSA, AES, and RSA-DES, I will create graphical plots showing: Encryption Time vs. Data Size (Performance Analysis) Brute-Force Resistance vs. Data Size (Security Analysis) Scalability vs. Data Size (Efficiency Analysis).

Figure 2: Encryption time vs Data Size.

In Figure 2 The Hybrid RSA-AES method (indicated in violet color) shows a marked deficiency during the encryption period to the individual RSA approach (representation in blue), while all maintain a safety level comparable. Contrary to this, the AES algorithm (painted in green) stands out in case of speed for data encryption, but there is still a reduction in providing a secure key exchange mechanism.

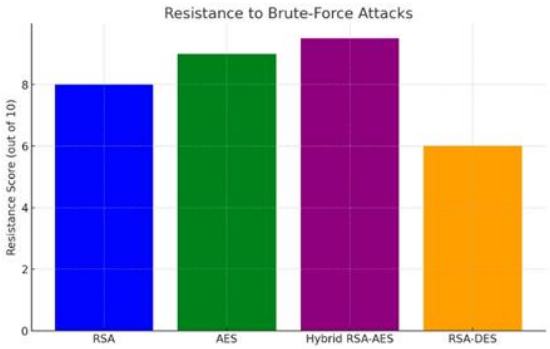

Figure 3: Resistance to brute force attacks.

Figure 3 illustrate the Hybrid architecture receives a better score of 9.5 out of 10, which is responsible for the implementation of Advanced Encryption Standards (AES) with Rival-Shamir-Adleman (RSA) algorithm, which combined strengthens security measures. Contrary to this, due to the underlying weaknesses associated with the RSA-DES configuration (representation in orange) data encryption standard (DES), receives a low score.

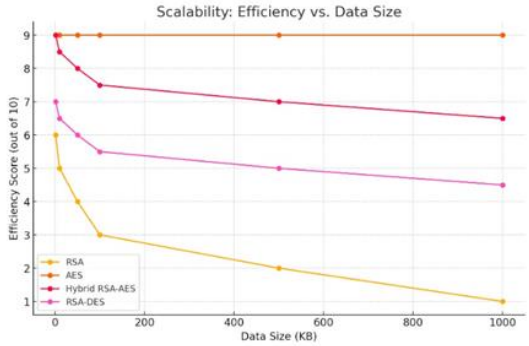

Figure 4: Efficiency vs. Data Size.

In Figure 4 Hybrid RSA-AES algorithm shows better efficiency in different data dimensions, more than the performance of RSA, and performs weak low efficiency compared to AEs when used independently. The hybrid RSA-AES system performs better in scalability compared to RSA-DES according to Key Size and Encryption Efficiency where AES uses larger key sizes (128, 192, 256 bits) compared to the DES that use (56 bits), and AES is faster than DES for encrypting large data, additionally Computational Overhead such that the hybrid system uses RSA only for key exchange, and AES handles the bulk data encryption, moreover Modern Algorithm Design and The combination of RSA and AES gives stronger security, Flexibility , Industry Adoption and Resistance to Attacks where the hybrid system shows better resistance to brute-force attack and other attacks.

The hybrid cryptographic system compared to a "two-layered lock such that RSA acts as the outer layer that securing the symmetric AES key during the transmission, and AES serves as inner layer such that protecting the actual data with the fast and the efficient encryption, this analogy highlights the work of the two layers together in order to provide strong security, computational and scalability efficiency, that making the system more suitable for the modern applications secure file transfer, IoT devices and cloud storage.

4 CONCLUSIONS

This scientific study introduces a hybrid RSA-AES cryptographic framework that includes the benefits of asymmetrical and symmetrical encryption function to establish a safe and effective data security paradigm. The proposed structure deals with the important challenges that rule in modern cryptography, including safe key exchange, effective data encryption and scalability requirements. By using RSA for secure protection of AES keys and by using AE -er for fast and flexible data encryption, hybrid function guarantees both adequate protection and optimal operating efficiency. Empirical findings suggest that the hybrid frame effectively consists of RSA -connected calculation overhead with A's early nature.

Framework provides formidable resistance to a range of cryptographic attacks, including Brute-Force and MAN-in-Media attacks, which provides a reliable solution to protect sensitive data in different applications. . In addition, the scalability of the framework provides the system for effective control of broad data sets, a significant requirement for modern applications such as secure cloud storage, encrypted communication and modern applications such as financial transactions. Although the structure shows significant benefits, it is not devoid of boundaries. Computer load imposed by RSA can still serve as a barrier to the resource limit environment, which requires further adaptation to understand its adequacy in domains such as Internet of Things (IoT) and mobile data processing. Possible research efforts can check the inclusion of mild cryptographic algorithms and sophisticated adaptation strategies to reduce these limitations. In the future work it can be exploring lightweight cryptographic algorithms for IoT, and integrating machine learning techniques to enhance security. Future work may explore

applications in educational technology, such as securing collaborative e-learning platforms [24].

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