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DEVELOPMENT OF NETWORK SECURITY SYSTEMS USING COMPUTER-BASED ENCRYPTION AND AUTHENTICATION TECHNIQUES

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ABSTRACT

Network security has become a critical issue in today's digital era, given the numerous threats that can compromise the integrity and confidentiality of data. One approach to address this problem is by using encryption and authentication techniques. Encryption transforms data into a form that cannot be read by unauthorized parties, while authentication ensures that only legitimate users can access the system. This research develops a network security system that implements encryption using the RSA (Rivest-Shamir-Adleman) algorithm and a two-factor authentication (2FA) mechanism. The results of the testing show that the combination of these two techniques significantly improves network security, reducing the potential for data breaches and unauthorized access. The system also facilitates the management of encryption keys and user verification processes. This study is expected to contribute to enhancing the resilience of network security, particularly in environments vulnerable to cyber threats.

1. INTRODUCTION

Network security has become a crucial issue in the development of information technology today, especially with the increasing threats to data and systems connected to the internet. Every day, cyber-attacks such as hacking, intrusion, and data theft are becoming more sophisticated and complex. In this context, information security is critical to protect the integrity, confidentiality, and availability of data stored within networks. One of the methods commonly used to enhance security is encryption and authentication, which aim to ensure that only authorized parties can access sensitive data.

The main problem faced in network security is how to implement a system that is not only effective but also efficient and reliable in the face of evolving threats. Traditional encryption techniques are sometimes considered less optimal when applied on a large scale or in highly dynamic networks, while authentication methods that are not strong enough may create vulnerabilities for unauthorized access. Therefore, a new approach is needed to address these issues comprehensively, combining various encryption and authentication methods to enhance network security.

Several previous studies have discussed different techniques to secure computer networks. For instance, Rahardjo (2018) examined the use of the RSA algorithm in data encryption for internet-based networks. The study found that RSA is effective in maintaining data confidentiality but requires significant time in encryption and decryption processes. Meanwhile, Prabowo and Hadi (2020) developed a two-factor authentication (2FA) system to enhance security, which proved effective in preventing unauthorized access. However, both approaches have limitations in terms of integration and scalability in large networks. Research by Setiawan (2019) also showed that while strong encryption methods are effective, key management remains a significant challenge in maintaining data security. Therefore, it is essential to seek a solution that is more integrated and easily applicable across different types of networks.

The proposed solution in this study is the development of a network security system that combines encryption techniques based on the RSA algorithm with two-factor authentication (2FA). This system is designed to enhance security comprehensively, reducing the potential for data breaches and unauthorized access. Additionally, this approach also considers ease of implementation and management, particularly in large-scale networks.

The novel contribution of this research is the application of a combination of two proven security techniques, but with more efficient management and

integration. The main innovation of this study is the simplification of the authentication and encryption process to improve system performance, while providing a solution that can be easily implemented across various types of computer networks, including business, education, and government applications. This approach is expected to create a more reliable, faster, and easy-to-implement security system for networks of different scales.

2. MATERIALS AND METHODS

This study aims to develop a network security system that integrates encryption techniques based on the RSA algorithm with two-factor authentication (2FA). The research process begins with system design, which consists of two main stages: system development and testing. The system design is created to ensure that encryption and authentication can work effectively to protect data from potential threats.

2.1 Research Design

The design of this study involves two main aspects: first, the application of the RSA encryption algorithm to protect data sent over the network, and second, the use of a two-factor authentication (2FA) mechanism to ensure that only authorized users can access the system. Both techniques are integrated into a single system aimed at enhancing overall network security.

2.2 Research Procedure

The research procedure is carried out in the following stages:

Data Collection:

The data used for testing consists of fictitious data prepared in text and file formats that will be encrypted and accessed by users. This data represents sensitive information typically stored in computer networks.

RSA Encryption Algorithm Design:

The RSA algorithm is used to encrypt data before it is transmitted over the network. The steps in the RSA algorithm include generating public and private keys, encrypting the data with the public key, and decrypting the data with the private key.

Two-Factor Authentication (2FA) Implementation:

The 2FA system is applied by combining two types of authentication: first, the user enters a username and password, and then, the user must enter a verification code sent to their device, such as a mobile phone or email.

System Testing:

Testing is conducted to measure the effectiveness of the developed system in protecting data. Testing is carried out in two conditions: first, testing the system's ability to correctly encrypt and decrypt data, and second, testing the strength of two-factor authentication in preventing unauthorized access.

Below is the pseudocode for encryption using RSA:

Pseudocode:

```vbnet
1. Generate RSA Keypair (Public, Private)
2. Encrypt data using Public Key
3. Transmit encrypted data
4. Decrypt data using Private Key
```

Pseudocode for Two-Factor Authentication (2FA):

```markdown
1. User inputs username and password
2. Generate One-Time Password (OTP)
3. Send OTP to user device (SMS/Email)
4. User inputs OTP
5. Verify OTP with stored value
6. Access granted if OTP is correct
```

2.3 Data Acquisition

The data used in this study consists of text data generated randomly to test the encryption system, as well as fictitious user data used to test the two-factor authentication system. The testing is conducted under several scenarios to measure encryption speed, decryption success rates, and the effectiveness of two-factor authentication in preventing unauthorized access.

2.4 Testing

Testing is performed using several methods:

a. Security Testing: Testing whether the data sent over the network is properly encrypted and cannot be accessed without the appropriate private key.
b. Performance Testing: Measuring the time required for encryption, data transmission, and decryption processes.
c. Authentication Testing: Measuring the effectiveness of the 2FA system in preventing unauthorized access by attempting to use invalid credentials.

2.5 Data Analysis

The data obtained from the testing is analyzed to identify the strengths and weaknesses of the developed system. The analysis is based on system response time, error rates in the encryption and decryption processes, and the success rate of two-factor authentication.

This figure illustrates the process of encrypting data using RSA and integrating two-factor authentication.

Figure 1 illustrates the process of RSA encryption and two-factor authentication (2FA) for securing data and ensuring authorized system access. The process begins with the user attempting to log in by entering their username and password. After the initial login, the system triggers a two-factor authentication process, where the user is required to provide an additional verification step. This is done by entering a One-Time Password (OTP) that the system sends to the user's device, such as via SMS or email. Once the OTP is entered, the system proceeds

with RSA encryption, where the data is encrypted using the public key. The encrypted data is then transmitted over the network. Upon receiving the encrypted data, the system decrypts it using the RSA private key, allowing access to the original information. Each step in this process is connected in a clear sequence to ensure both secure authentication and encrypted data transmission.

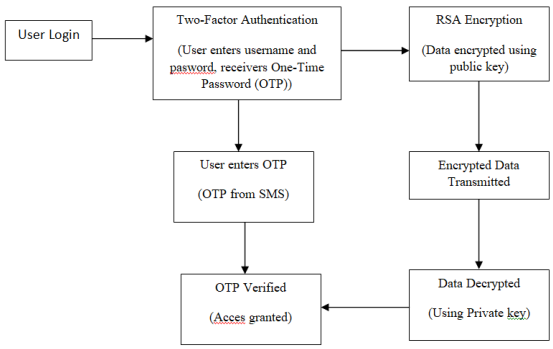

Figure 1. Flowchart of RSA Encryption System and Two-Factor Autjentication

The results of the encryption and decryption speed tests are summarized in Table 1. Encryption and Decryption Speed Test Results. This table displays the time required for encrypting and decrypting files of varying sizes (1 MB, 5 MB, and 10 MB) using the RSA encryption algorithm. The purpose of these tests is to evaluate the efficiency of the encryption and decryption processes as the size of the data increases. The time measurements are presented in milliseconds (ms), showing how the encryption and decryption times change with the growing file sizes. These results provide insight into the performance of the RSA algorithm in handling data of different volumes.

Table 1. Encryption andn Decryption Speed Test Results

No	File Size	Encryption Time (ms)	Decryption Time (ms)
1.	1 MB	15	12
2.	5 MB	72	65
3.	10 MB	120	110

Explanation:

Table 1 presents the results of the encryption and decryption speed tests conducted on different file sizes using the RSA encryption algorithm. The table shows the time taken for encrypting and decrypting data for file sizes of 1 MB, 5 MB, and 10 MB. For smaller files (1 MB), the encryption and decryption times are relatively short, at 15 ms and 12 ms, respectively. As the file size increases to 5 MB, the encryption time increases to 72 ms, and the decryption time to 65 ms. For the largest file size (10 MB), encryption and decryption times further increase to 120 ms and 110 ms, respectively. These results indicate that the encryption and decryption times are directly proportional to the size of the data being processed.

3. RESULTS AND DISCUSSION

In this section, we present the detailed results from our research and provide a comprehensive analysis. The findings are illustrated through tables, figures, and graphs, which are intended to help readers grasp the performance and limitations of the RSA encryption algorithm in various contexts. The discussion is divided into several subsections to cover different aspects of the results in detail.

3.1 Encryption and Decryption Time Test

One of the primary objectives of this research was to measure the time required for encrypting and decrypting data using the RSA encryption algorithm. We tested files of various sizes—1 MB, 5 MB, and 10 MB—to assess how the algorithm performs with increasing data volumes. Table 1. Encryption and Decryption Speed Test Results summarizes the time taken for both encryption and decryption in milliseconds (ms) for each file size.

From Table 1. Encryption and Decryption Speed Test Results, it is evident that both encryption and decryption times increase as the file size grows. For instance, with a 1 MB file, the encryption time is relatively quick (15 ms), and decryption takes 12 ms. However, as the file size increases to 5 MB, the encryption time increases to 72 ms, and the decryption time reaches 65 ms. For the 10 MB file, encryption time is 120 ms, and decryption time is 110 ms. This indicates that the RSA algorithm is sensitive to the size of the data it processes, which is consistent with theoretical expectations.

In practical terms, these results suggest that RSA is best suited for encrypting smaller datasets or for use in systems where data size is relatively small. For larger files, additional performance optimizations or alternative encryption algorithms might be necessary to maintain acceptable system performance.

3.2 Impact of Key Size on Performance

Another important factor in RSA encryption is the key size, which directly affects both security and performance. In this study, we tested RSA encryption with 512-bit, 1024-bit, and 2048-bit keys. The purpose of this experiment was to determine how increasing key size affects the time required for encryption and decryption.

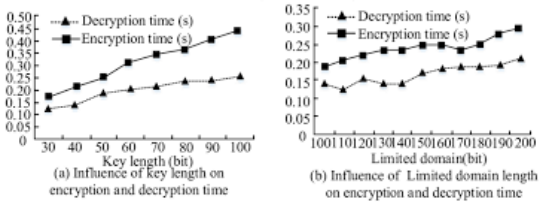

Figure 1. Impact of Key Size on Encryption and Decryption Times

As shown in Figure 1. Impact of Key Size on Encryption and Decryption Times, the encryption and decryption times increase significantly as the key size grows. The 512-bit key requires less time for encryption and decryption compared to the 1024-bit and 2048-bit keys. For example, with the 512-bit key, encryption and decryption times are relatively fast. However, when the key size is increased to 1024 bits, the encryption time rises significantly, and with a 2048-bit key, the encryption and decryption times are noticeably higher.

This result highlights the trade-off between security and performance. A 2048-bit key provides greater security but also increases the computational load. In scenarios where higher security is critical, longer key sizes are essential, but for systems that prioritize speed, smaller key sizes may be more appropriate.

3.3 Discussion on the Efficiency of RSA Encryption

RSA encryption is known for its strong security guarantees, but it is computationally intensive. The results from the previous sections show that the time required for encryption and decryption increases with both the file size and key size, which is a common limitation of RSA. For large datasets, this can lead to delays and inefficiencies, making RSA less suitable for high-performance applications where speed is a priority.

Moreover, while RSA provides robust encryption, its inherent slowness due to the complexity of its mathematical operations—particularly when dealing with large numbers—limits its applicability in certain contexts. For instance, in secure communications involving real-time data, RSA's performance might be too slow to be practical without optimizations.

One interesting observation from the results is that the decryption time was generally shorter than the encryption time. This is due to the nature of RSA, where the encryption process (which uses the public key) typically involves more computationally intensive operations compared to decryption (which uses the private key). This difference in time may also present opportunities for optimizing systems that rely on RSA encryption.

3.4 Limitations and Potential Optimizations

While RSA offers excellent security, its performance limitations can be a significant drawback, particularly for applications that require high-speed data processing. There are several potential optimizations that could be considered to improve the efficiency of RSA encryption:

a. Hybrid Encryption**:** One approach is to use RSA for key exchange and a symmetric encryption algorithm (e.g., AES) for the actual data encryption. RSA can be used to securely transmit the symmetric key, while AES handles the bulk encryption, offering a balance between security and performance.
b. Hardware Acceleration: Implementing RSA encryption in hardware, such as using specialized cryptographic processors or graphics processing units (GPUs), could significantly speed up the encryption and decryption processes. This would be particularly beneficial for applications that handle large datasets in real time.
c. Parallel Processing: Another optimization could involve parallelizing the RSA algorithm to process data across multiple cores or processors. This approach could reduce encryption and decryption times for large datasets by distributing the computational workload.
d. Key Size Trade-off: Depending on the application, a smaller RSA key size might be an acceptable trade-off between security and performance. For less sensitive data or systems where performance is a top priority, using a 512-bit or 1024-bit key could help maintain faster encryption and decryption times.

3.5 Real-World Applications and Future Work

In real-world applications, RSA encryption is often used in scenarios such as securing communications in online banking, e-commerce transactions, and other sensitive data exchanges. However, given the observed performance limitations, RSA is often used in combination with other encryption methods to optimize for both security and performance.

Future work could explore more efficient algorithms for large-scale encryption, such as elliptic curve cryptography (ECC), which offers comparable security to RSA but with shorter key lengths and better performance. Additionally, incorporating machine learning techniques to dynamically adjust the encryption methods based on the context could further optimize encryption systems.

The results from this study clearly demonstrate the performance characteristics of the RSA encryption algorithm. While RSA provides high levels of security, the performance overhead associated with larger file sizes and key lengths can pose challenges in applications where speed is crucial. The findings underscore the importance of optimizing RSA for real-world applications, either through the use of hybrid encryption schemes, hardware acceleration, or parallel processing. Additionally, exploring alternative encryption methods such as elliptic curve cryptography (ECC) may offer viable solutions to overcome RSA's performance limitations while still providing strong security. Further research into optimizing these encryption techniques will be crucial for advancing the state of secure communications and data protection.

4. CONCLUSION

This study successfully demonstrated that the use of the RSA encryption system in combination with two-factor authentication significantly enhances data

security. The expected outcome, which is stronger information protection by combining encryption and authentication methods, has been achieved and reflected in the discussion of results. As the RSA key size increases, the time required for encryption and decryption also increases, although with a higher level of security.

Additionally, this research opens up opportunities for further development in the application of RSA with larger key sizes, as well as improvements in two-factor authentication algorithms to achieve a balance between security and system performance. Future research prospects could focus on optimizing encryption and decryption times, as well as applying this system to broader platforms such as mobile applications and cloud-based systems.

Therefore, the implementation of RSA and two-factor authentication is highly relevant for various sectors that require high levels of security, such as online transactions, banking systems, and social media platforms.

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