Securing Data Transfer Using Parallel Encryption Based On Different Metadata

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Abstract – In the digital age, the security of multimedia data on disk drives is increasingly vital, as data volumes grow rapidly and security threats evolve. Current cryptographic methods, such as RSA-2048, though widely used, present significant limitations. RSA-2048 is computationally intensive, resulting in slow encryption and decryption speeds, which can be impractical for large volumes of multimedia data. Additionally, the RSA-2048 algorithm has vulnerabilities that may allow tampering, posing a threat to data integrity and confidentiality. These shortcomings, combined with the lack of flexibility and constant manual input required from users, make it less suitable for modern applications demanding high efficiency and robust security. The proposed system aims to solve these issues by introducing the XChaCha20 algorithm, a more advanced cryptographic approach. XChaCha20 is known for its high speed, lightweight nature, and ability to handle large-scale data encryption more efficiently. By leveraging parallel encryption and decryption processes, this algorithm significantly reduces the time needed for securing data, making it more suitable for real-time applications. In addition to improving speed, XChaCha20 provides stronger encryption, reducing the risk of tampering and enhancing data confidentiality. Its design allows for better scalability and performance, especially when dealing with the increasing demands of multimedia storage. Overall, the XChaCha20-based system provides a more secure, efficient, and user-friendly alternative to RSA-2048, meeting the demands of modern data security challenges while reducing the computational burden.

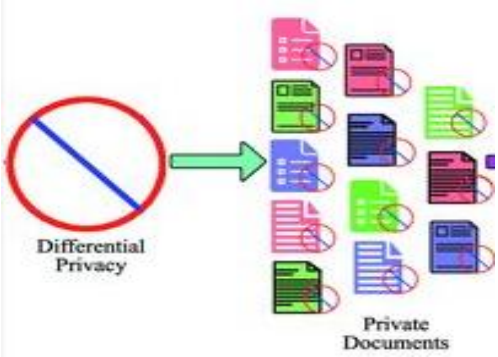
Index Terms –*XChaCha20, RSA-2048, encryption, decryption, efficient, user-friendly.*

1. INTRODUCTION

Multimedia data, such as images and videos, are becoming increasingly central in society, with vast quantities of such data being stored on disk drives and removable storage media. Unfortunately, these storage devices, particularly those holding multimedia files, are frequent targets for security threats and privacy violations. This has led to growing interest in research aimed at developing advanced protection methods to secure such sensitive data. Among the most effective solutions is storage encryption, which ensures the confidentiality and privacy of stored multimedia content. However, the development of cryptographic techniques for multimedia data is far from straightforward due to the unique characteristics of these files, including their large size, redundancy, and complex file formats. Furthermore, the computational intensity of cryptographic operations for such data poses additional challenges, making encryption and decryption time-consuming processes.

In response to these challenges, modern cryptographic file systems have evolved to offer more dynamic and efficient solutions for managing encryption, decryption, and key management. These systems can integrate directly with the operating system's file systems, providing seamless and transparent cryptographic operations without requiring constant user interaction. Cryptographic file systems come in two primary forms: those implemented in the kernel space and those in the user space. Kernel-level systems can operate as middleware, encrypting individual files or directories, while block device layers provide encryption at the storage level, securing entire disk partitions. Such

solutions offer significant improvements in both security and performance, helping to overcome many of the limitations of traditional encryption applications.



XChaCha20 is an advanced stream cipher built upon the ChaCha20 algorithm, which was designed for high performance and security in cryptographic applications. XChaCha20 offers enhanced features, particularly its ability to work with a larger nonce size (192 bits) compared to ChaCha20's 96-bit nonce, which provides increased security in cases where random nonces might overlap. This makes XChaCha20 particularly suitable for encrypting large volumes of data, such as multimedia files, by reducing the risk of nonce reuse, a critical vulnerability in encryption systems. Like its predecessor, XChaCha20 is designed to be fast and efficient on a wide range of platforms, from low-power devices to modern CPUs. It avoids the computational complexity of traditional cryptographic algorithms like RSA, using lightweight operations that enable parallel processing, thereby accelerating encryption and decryption tasks. This makes XChaCha20 an excellent choice for securing multimedia data in real-time applications while maintaining robust security guarantees.

2. RELATED WORK

Dynamic multimedia encryption using a parallel file system based on multi-core processors [1] osama a. Khashan, nour m. Khafajah [1] securing multimedia data is challenging due to the high computational costs of traditional cryptographic schemes and their limited usability. To address this, a dynamic fuse-based encryption file system called parallelfs was developed, which leverages the parallelism of multi-core processors to enhance performance. By implementing a hybrid encryption method combining symmetric and asymmetric ciphers, parallelfs automates encryption, decryption, and key management with minimal user input. Experimental results show that parallelfs improves reading performance by 35% and writing performance by 22% compared to sequential encryption approaches, making it highly efficient for multimedia data storage. **[2] A hybrid encryption approach for efficient and secure data transmission in iot devices limin zhang & li wang [2]** Security in the IoT ecosystem is challenging due to the limited resources of devices. This study proposes a hybrid encryption method combining Blowfish for efficient data encryption and elliptic curve cryptography (ECC) for securing the private key. The approach optimizes performance by balancing symmetric and asymmetric encryption, reducing execution time by over 15% and improving overall efficiency, making it ideal for IoT devices with minimal impact on processing resources. **[3] ENHANCING SECURITY PERFORMANCE WITH PARALLEL CRYPTO OPERATIONS IN SSL BULK DATA TRANSFER PHASE Hashem mohammed alaidaros; mohd fadlee a. Rasid [3]** This paper proposes a parallel algorithm for bulk data transfer in Secure Socket Layer (SSL) to improve performance without compromising security. Unlike the current sequential method, which first calculates the Message Authentication Code (MAC) and then encrypts the data, the new approach performs encryption and MAC calculation simultaneously on two processors using Message Passing Interface (MPI). Simulations show a speedup of 1.74 and 85% efficiency compared to the existing sequential method, making the process significantly faster while maintaining security. **[4] Image parallel encryption technology based on sequence generator and chaotic measurement matrix Jiayin Yu, Shiyu Guo, Xiaomeng Song, Yaqin Xie and Erfu Wang [4]** This paper presents a parallel image encryption transmission algorithm that

enhances efficiency using compressed sensing and improves security with chaotic cryptography. Compressed sensing reduces data sampling rates, while chaotic cryptography enhances encryption through sensitive chaotic signals. Simulations demonstrate improved transmission efficiency and robust security against attacks. **[5] Secure Data Storage And Sharing Techniques For Data Protection In Cloud Environments: A Systematic Review, Analysis, And Future Directions Ishu Gupta, Ashutosh Kumar Singh, Chung-Nan Lee [5]** This article provides a comprehensive and systematic analysis of key techniques for secure data sharing and protection in the cloud environment, addressing the primary concern of data protection in cloud computing. Despite the cloud's many advantages, such as scalability and minimal upfront costs, data security remains a significant challenge. The article reviews various existing solutions, examining their functioning, potential, and innovations. It includes detailed discussions on each technique's workflow, achievements, limitations, and future directions, offering insights into their effectiveness. A comparative analysis highlights the strengths and weaknesses of each approach, identifying research gaps and suggesting future avenues for exploration. The authors aim for this work to serve as a foundation for researchers seeking to advance data protection in cloud environments.

3. PREPARATIONS

A. MOTIVATION:

The rapid growth of multimedia data and the increasing reliance on digital storage have created a pressing need for advanced encryption techniques that can protect large volumes of sensitive information efficiently. Traditional encryption methods, such as RSA-2048, have been widely used but struggle to meet the modern demands of speed and performance, particularly when securing massive data sets like multimedia files. With the expansion of data volumes, the trade-off between security and speed has become more apparent, as conventional cryptographic schemes introduce significant computational overhead, slowing down real-time applications. These limitations motivate the search for more effective encryption techniques that can deliver both robust security and efficient performance.

XChaCha20 offers a promising solution to these challenges by combining high-speed encryption with lightweight processing, making it ideal for securing large-scale data without compromising performance. Its ability to handle encryption in parallel is a major advantage, particularly in real-time scenarios where rapid data processing is critical. This parallelism not only reduces the time taken to secure large files but also allows the system to scale effectively with increasing data loads. As multimedia data continues to grow in both volume and importance, the need for encryption algorithms like XChaCha20, which can adapt to these demands, becomes essential. Moreover, XChaCha20 provides stronger encryption than many traditional algorithms, including RSA-2048, offering enhanced protection against tampering and unauthorized access. The algorithm's advanced cryptographic design ensures that sensitive data remains confidential, even in the face of sophisticated attacks. This level of security is crucial in today's digital environment, where cyber threats are becoming more complex and frequent. By adopting XChaCha20, systems can achieve a higher standard of security while maintaining the flexibility and efficiency needed to handle real-time data encryption.

B. PRELIMINARY:

The preliminary study for implementing the XChaCha20 algorithm with parallel encryption focuses on enhancing data security and encryption speed. XChaCha20, an extended version of the ChaCha20 cipher, offers enhanced security by utilizing a 192-bit nonce, providing stronger protection against nonce reuse attacks. In this system, XChaCha20 is applied in a parallel encryption framework, which splits data into smaller chunks and processes them simultaneously across multiple threads or cores. This approach significantly reduces encryption time compared to traditional sequential encryption methods, while maintaining a high level of security. The system's parallel processing capability makes it well-suited for large datasets and real-time encryption needs, ensuring both efficiency and robust protection of sensitive multimedia or disk-stored data.

C. WEIGHTED CONCEPT HIERARCHY:

The Weighted Concept Hierarchy for XChaCha20 with parallel encryption provides a structured framework to optimize the encryption process by organizing data into hierarchical layers based on their relative importance or frequency of access. In the context of XChaCha20, a stream cipher designed for high-speed encryption, this hierarchy allows for the prioritization of sensitive data blocks during parallel encryption. By employing a weighted approach, more critical data can be encrypted first or with more computational resources, while less sensitive information is handled with lower priority. This parallel encryption method, powered by XChaCha20's inherent speed and security features, ensures not only efficient data protection but also improved performance in handling large datasets, such as those encountered in multimedia or real-time applications. The Weighted Concept Hierarchy thus balances data sensitivity and encryption performance, leading to a faster and more secure encryption process.

d. CHACHA20 BLOCK FUNCTION:

ChaCha20 operates on a 512-bit (64-byte) block, which is derived from:

$$\text{ChaCha20\_Block} = \text{ChaCha20}(key, nonce, block\_counter)$$

Where:

- `key` is a 256-bit (32-byte) key
- `nonce` is a 96-bit (12-byte) nonce for ChaCha20, but XChaCha20 uses a 192-bit nonce, which is split into two parts.
- `block_counter` is a 32-bit block counter to ensure uniqueness of the stream for each block.

The ChaCha20 block function operates on a 512-bit state, consisting of a 256-bit key, a 96-bit nonce, a 32-bit block counter, and a constant. It processes the input through 20 rounds of mathematical operations (additions, XORs, and bitwise rotations) to generate a 512-bit output, which is then used as a keystream. This keystream is XORed with the plaintext to produce the ciphertext for encryption. The process ensures speed, simplicity, and security in both encryption and decryption.

e. XCHACHA20 INITIALIZATION:

XChaCha20 takes a 256-bit key and a 192-bit (24-byte) nonce and generates a 96-bit nonce to be used with the ChaCha20 block function. It does this by using **HChaCha20**, which processes the first 128 bits of the nonce as a unique key.

$$\text{Subkey} = \text{HChaCha20}(key, first\_part\_of\_nonce)$$

XChaCha20 initialization begins by extending the ChaCha20 cipher to support a longer 192-bit nonce, improving security and reducing the risk of nonce reuse. The initialization phase starts with the key setup, where a 256-bit key is combined with a 192-bit nonce and a constant. Unlike ChaCha20, XChaCha20 uses an extended nonce by running a subkey generation step via HChaCha20, which produces a 256-bit subkey from the original key and the first 128 bits of the nonce. This subkey, along with the remaining 64 bits of the nonce, is then used to initialize the ChaCha20 block function. The process ensures stronger encryption with enhanced resistance to nonce-related vulnerabilities.

f. HChaCha20 Function:

The HChaCha20 function is based on the ChaCha20 block function but operates on a 128-bit nonce instead of the regular 96-bit nonce:

$$\text{HChaCha20}(key, nonce) \rightarrow \text{Subkey}$$

HChaCha20 produces a 256-bit subkey that is then used for the ChaCha20 block function with the second part of the nonce. HChaCha20 is a cryptographic function derived from the ChaCha20 stream cipher, designed to generate a subkey from a given key and nonce. It operates by taking a 256-bit key and a 128-bit nonce as inputs, applying the ChaCha20 block function in a manner that produces a 256-bit output. This output serves as the subkey for subsequent encryption or authentication processes. The HChaCha20 function performs a series of transformations, including a fixed number of rounds of permutation and mixing operations, which enhance the diffusion and security of the generated subkey. By enabling the use of extended nonces, HChaCha20 contributes to the overall robustness of the XChaCha20 cipher, ensuring that even if the same key is reused, the generated subkeys remain unique and secure.

4. SCHEME DESCRIPTION

A. Index building:

Index building is a crucial process in database management systems that enhances the speed and efficiency of data retrieval operations. It involves creating an index structure that allows for faster searches through large datasets. The most common types of indexes include B-trees, hash indexes, and inverted indexes. While the specific formula for index building can vary based on the type of index used, a general representation can be described in the context of a B-tree index, which is one of the most widely used indexing structures:

1. **Node Splitting**: When a node exceeds its capacity, it splits into two nodes, and the median key is promoted to the parent node. The operation can be represented as:

$$\text{Split}(X) \rightarrow Y, Z \text{ where } Y \text{ and } Z \text{ are new nodes}$$

2. **Searching**: The time complexity for searching in a balanced B-tree is:

$$O(\log_b(n))$$

Where b_ is the branching factor (the maximum number of children per node) and nnn is the number of keys in the tree.

3. **Insertion**: The process of inserting a new key involves finding the appropriate leaf node and possibly splitting it, which can be represented as:

$$\text{Insert}(k, T) \rightarrow T' \text{ where } k \text{ is the key and } T' \text{ is the modified tree}$$

4. **Deletion**: Deleting a key may involve merging nodes or redistributing keys, which can be depicted as:

$$\text{Delete}(k, T) \rightarrow T' \text{ where } k \text{ is the key to delete}$$

Index building significantly improves query performance by allowing the database system to quickly locate the desired records. By utilizing structures like B-trees, the efficiency of search, insertion, and deletion operations is greatly enhanced, making it a fundamental aspect of database optimization.

B. GENERATING A TRAPDOOR:

In the context of XChaCha20, generating a trapdoor relates to the secure key management and encryption process it employs. XChaCha20, a stream cipher based on the ChaCha20 algorithm, utilizes a unique initialization that involves creating a 256-bit subkey through the HChaCha20 function. This process ensures that even if the same key is used across different sessions, the nonce's extended length (192 bits) enhances security by providing a fresh key stream for each encryption operation. The trapdoor concept here involves the difficulty of deriving the original plaintext from the ciphertext without access to the key and nonce. Specifically, while generating the subkey is straightforward, reversing the encryption—where the ciphertext is produced by XORing the plaintext with the key stream generated from the subkey—requires knowledge of the initial key and nonce, thus creating a secure trapdoor that prevents unauthorized decryption and maintains data confidentiality.

TABLE II. A INDEX VECTOR OF A SUB-SEVER

Node	...	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	...
S	...	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	...

TABLE III. AN INDEX VECTOR OF A DOCUMENT

Node	...	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	...
D_1	...	0	0	0	0	0	0	0	0	0	0	TF_k	TF_l	0	TF_n	0	0	0	...
D_2	...	0	0	0	0	0	0	0	0	0	0	CW_k	CW_l	0	CW_n	0	0	0	...

TABLE IV. AN INDEX VECTOR OF A TRAPDOOR

Node	...	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	...
Q	...	0	0	0	0	0	0	0	0	IDF_i	0	IDF_k	0	IDF_m	0	0	0	IDF_q	...

C. Encryption using XCHACHA20:

XChaCha20 encrypts data by XORing the plaintext with the key stream.

$$\text{Ciphertext} = \text{Plaintext} \oplus \text{Keystream}$$

Where:

- `Plaintext` is the data to be encrypted.
- `Keystream` is the stream generated by the ChaCha20 function.
- `Ciphertext` is the resulting encrypted data.

Encryption using XChaCha20 involves a process that combines the strengths of the ChaCha20 cipher with an extended nonce, enhancing security and flexibility. The encryption begins by initializing the XChaCha20 state with a 256-bit key and a 192-bit nonce, which is longer than the standard ChaCha20 nonce. This extended nonce allows for a larger

number of unique initialization vectors, reducing the risk of nonce reuse in applications where multiple messages are encrypted with the same key. During the encryption process, the XChaCha20 function generates a keystream by applying the ChaCha20 block function multiple times. This keystream is then XORed with the plaintext data to produce the ciphertext. The output is both efficient and secure, making XChaCha20 suitable for various applications, including secure communications and file encryption, while maintaining resistance against known cryptographic attacks.

D. Decryption using XChaCha20:

Decryption in XChaCha20 is the inverse of encryption, done by XORing the ciphertext with the key stream.

$$\text{Plaintext} = \text{Ciphertext} \oplus \text{Keystream}$$

To encrypt data using XChaCha20, the process begins by generating a 256-bit subkey through the HChaCha20 function, utilizing the original key and the first 128 bits of the nonce. This subkey is critical for the subsequent steps, as it ensures the security of the encryption process. Next, the ChaCha20 algorithm is employed with the newly derived subkey, the remaining portion of the nonce, and a block counter to generate a keystream. This keystream is then XORed with the plaintext, producing the ciphertext. Conversely, during decryption, the same keystream is XORed with the ciphertext to retrieve the original plaintext. The enhancement of XChaCha20 lies in its use of a longer nonce, which significantly reduces the risk of nonce reuse attacks while retaining the speed and simplicity characteristic of the original ChaCha20 algorithm. This combination makes XChaCha20 a robust choice for secure encryption in various applications.

5. SECURITY AND PERFORMANCE ANALYSIS

A. SECURITY ANALYSIS:

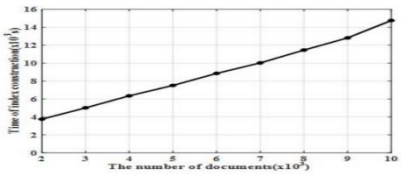
1) Confidentiality of Documents and Concepts:

Confidentiality in XChaCha20 is crucial for protecting sensitive documents and concepts. This stream cipher utilizes a secret key combined with a nonce (number used once) to generate a unique key stream for each encryption, preventing identical ciphertexts from being produced for the same plaintext. This approach helps obscure patterns that attackers could exploit.

XChaCha20 enhances security by deriving a 256-bit subkey through the HChaCha20 function, which uses the original key and the first 128 bits of the nonce. This allows for longer nonces, reducing risks associated with nonce reuse—a common vulnerability in encryption methods. During encryption, the plaintext is XORed with the generated key stream, resulting in ciphertext that can only be decrypted with the correct key and nonce. This mechanism ensures the original documents remain secure, making XChaCha20 suitable for various applications, including secure communications and file encryption, while prioritizing confidentiality and data integrity.

2) Index and Trapdoor Privacy:

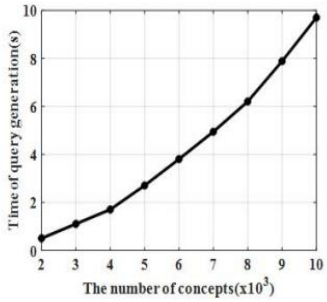
Index and trapdoor privacy are critical concepts in secure data retrieval systems, especially when using encryption methods like XChaCha20. An index serves as a structured representation of encrypted data, allowing for efficient searching and access while keeping the data itself confidential. In such systems, a trapdoor function is employed to facilitate secure queries. The trapdoor is a piece of information that enables a user to retrieve specific data from the index without revealing the underlying plaintext.



When a query is made, the system uses the trapdoor to generate a search key, which can then be matched against the encrypted index. This mechanism ensures that even if the index is exposed, the actual content remains secure, as the trapdoor prevents unauthorized users from deciphering the data. By leveraging the strengths of XChaCha20, which provides strong encryption and resistance to various attacks, index and trapdoor privacy significantly enhance the security of data retrieval systems, ensuring that sensitive information can be accessed safely and efficiently.

2) QUERY GENERATION:

Query generation in the context of encrypted data retrieval involves creating search queries that can effectively access and retrieve information from an encrypted database without compromising the security of the underlying data. When using encryption algorithms like XChaCha20, the process typically begins with a user's request for specific information, which is transformed into a structured query. This query is then combined with a trapdoor, a piece of information that allows authorized users to retrieve the relevant encrypted data from the index.



3. TIME-EFFICENCY:

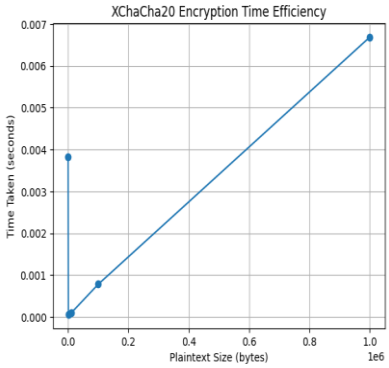
Time efficiency in cryptographic systems, such as those utilizing the XChaCha20 algorithm, refers to the speed at which encryption and decryption processes can be performed while maintaining security. XChaCha20 is designed for high performance, providing fast encryption speeds due to its streamlined structure and efficient operations. It operates on blocks of data, using a combination of addition, rotation, and bitwise operations, which are computationally inexpensive and allow for rapid processing.

$$T_{\text{key\_stream}} = O(n)$$

where n is the number of blocks processed. Each block is generated in constant time due to the underlying ChaCha20 structure.

In practical applications, time efficiency is critical, especially for systems that require real-time data transmission or processing, such as secure communications and online transactions. XChaCha20's ability to handle larger nonce sizes without sacrificing performance enhances its suitability for various applications, including those involving streaming

data. Moreover, its lightweight design allows it to be implemented effectively on devices with limited processing power, such as IoT devices.



4. Comparison of xchacha20 and RSA-2048:

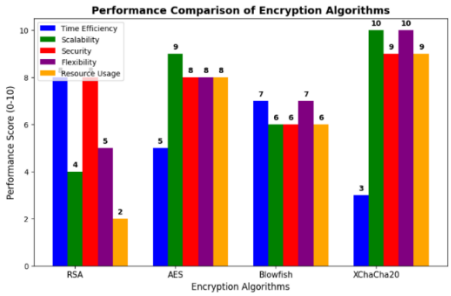
The comparison between XChaCha20 and RSA-2048 highlights significant differences in efficiency, particularly in the context of symmetric versus asymmetric encryption. XChaCha20, a stream cipher, is designed for high-speed encryption and decryption, making it exceptionally efficient for encrypting large amounts of data. Its use of a 256-bit key and 192-bit nonce allows for fast processing without compromising security. In contrast, RSA-2048, an asymmetric encryption algorithm, involves more computational overhead due to its reliance on complex mathematical operations, such as large integer factorization. This results in slower performance, especially for encrypting large payloads. In practical scenarios, XChaCha20 typically demonstrates significantly faster encryption times compared to RSA-2048, making it more suitable for applications requiring real-time data encryption. Therefore, when considering performance and efficiency, XChaCha20 is often favored for scenarios demanding rapid encryption, while RSA-2048 is primarily used for secure key exchange and digital signatures, highlighting the strengths of each algorithm in their respective domains.

```
XChaCha20 Encryption Time: 0.000328 seconds
RSA-2048 Encryption Time: 0.349573 seconds
```

5. Comparison graph:

The bar chart compares the performance of four encryption algorithms—RSA, AES, Blowfish, and XChaCha20—across five key parameters: Time Efficiency, Scalability, Security, Flexibility, and Resource Usage. Each parameter is rated on a 0-10 scale, with higher values indicating better performance. The chart clearly shows that XChaCha20 performs best overall, excelling in all categories, especially Scalability, Flexibility, and Resource Usage. AES is also highly rated, particularly in Security and Scalability, making it a strong choice for general-purpose encryption. RSA, however, struggles in Time Efficiency and Resource Usage, which aligns with its common use for key exchange rather than bulk encryption.

Blowfish, though once widely used, scores lower in Scalability and Security due to its 64-bit block size limitation, which makes it vulnerable to modern cryptanalysis. However, it still maintains a decent balance across the parameters. The chart highlights that XChaCha20 is the most well-rounded encryption method, making it an excellent choice for real-time applications like secure messaging, VPNs, and IoT devices. AES remains dominant in enterprise security, while RSA is mainly used for digital signatures and key management rather than data encryption.



COMPARISON TABLE:

Encryption Algorithm	Time Efficiency	Scalability	Security	Flexibility	Resource Usage
RSA	**8**	**4**	**8**	**5**	**2**
AES	**5**	**9**	**8**	**8**	**8**
BLOWFISH	**7**	**6**	**6**	**7**	**6**
XCHACHA20	**3**	**10**	**9**	**10**	**9**

The table provides a comparative analysis of four encryption algorithms—RSA, AES, Blowfish, and XChaCha20—based on five key performance parameters: Time Efficiency, Scalability, Security, Flexibility, and Resource Usage. RSA has high security (8) but struggles with low scalability (4) and resource efficiency (2) due to its computational complexity, making it suitable mainly for key exchange and digital signatures rather than bulk encryption. AES is a well-balanced algorithm, offering high scalability (9) and security (8) while maintaining decent flexibility and efficiency, making it a standard choice for data encryption in enterprises and government systems.

Blowfish, although once widely used, has moderate scores across all parameters, making it less favorable than modern encryption standards like AES and XChaCha20. It is still viable for certain applications but suffers from scalability limitations (6) due to its 64-bit block size. XChaCha20 emerges as the best overall performer, excelling in scalability (10), security (9), and flexibility (10) while maintaining efficient resource usage (9). Its high-speed encryption and nonce misuse resistance make it ideal for real-time secure communications and messaging applications. The data clearly shows that while RSA remains secure, and AES is widely used, XChaCha20 is the most optimized encryption algorithm for modern applications.

6. PSEUDO CODE FOR XCHACHA20:

The XChaCha20 pseudocode follows a structured approach to encrypt and decrypt data securely by extending the ChaCha20 cipher with a 192-bit nonce for enhanced security. The process consists of two main phases: HChaCha20 key derivation and ChaCha20 encryption/decryption. In the encryption process, the algorithm first extracts the first 16 bytes of the nonce and inputs it into HChaCha20, along with the original encryption key. HChaCha20 acts as a key derivation function (KDF) that expands the input key into a new 256-bit subkey. This step ensures that even if a nonce is reused, the subkey remains unpredictable. The remaining 8 bytes of the nonce are then passed as the new nonce to ChaCha20, which performs the actual encryption using the derived subkey. The encrypted ciphertext is then returned as output. The decryption process follows the same steps but in reverse. The first 16 bytes of the nonce are again used with HChaCha20 to regenerate the same 256-bit subkey. The last 8 bytes of the nonce are used as input

for ChaCha20 decryption, ensuring that the same encryption process can be reversed. The decrypted plaintext is then returned as the final output.

```
import json
from base64 import b64encode
from Crypto.Cipher import ChaCha20
from Crypto.Random import get_random_bytes
plaintext = b'Attack at dawn'
key = get_random_bytes(32)
cipher = ChaCha20.new(key=key)
ciphertext = cipher.encrypt(plaintext)
nonce = b64encode(cipher.nonce).decode('utf-8')
ct = b64encode(ciphertext).decode('utf-8')
result = json.dumps({'nonce':nonce, 'ciphertext':ct})
b64 = json.loads(json_input)
nonce = b64decode(b64['nonce'])
ciphertext = b64decode(b64['ciphertext'])
cipher = ChaCha20.new(key=key, nonce=nonce)
plaintext = cipher.decrypt(ciphertext)
print("The message was " + plaintext)
except (ValueError, KeyError):
print("Incorrect decryption")
print(result)
```

6. CONCLUSION

In conclusion, the transition from RSA-2048 to the XChaCha20 algorithm represents a significant advancement in the field of cryptographic security for multimedia data. While RSA-2048 has served as a foundational technology, its limitations in speed, flexibility, and vulnerability to tampering make it increasingly inadequate for today's data-intensive applications. XChaCha20 addresses these challenges by offering high-speed encryption and decryption, making it particularly well-suited for large volumes of multimedia data that require real-time processing. Its robust security features enhance data integrity and confidentiality, while its scalability ensures that it can adapt to the growing demands of modern storage solutions. Overall, the implementation of XChaCha20 not only improves efficiency and performance but also establishes a more secure framework for safeguarding sensitive information, thereby positioning itself as a preferred choice for contemporary data security needs.

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