Beating Post Quantum Cryptographic Technique

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Abstract:

Post-quantum cryptography (PQC) aims to provide cryptographic algorithms, protocols, and systems that can resist attacks from quantum computers. Quantum computers have the potential to break widely used public-key cryptosystems, necessitating the development of alternative solutions. PQC techniques involve mathematical problems that are challenging for both classical and quantum computers to solve, such as lattice-based cryptography, codebased cryptography, hash-based cryptography, and multivariate cryptography. These techniques require larger key sizes but offer long-term security against quantum attacks.

This paper proposes the use of two encryption algorithms, AES (Advanced Encryption Standard) and ChaCha20, to mitigate the risks posed by post-quantum computing. AES is a symmetric encryption algorithm widely regarded as secure and efficient. It operates on blocks of data and supports key sizes of 128, 192, and 256 bits. ChaCha20, designed by Daniel J. Bernstein, is a secure and efficient stream cipher often used with the Poly1305 message authentication code.

The paper discusses the security, speed, key sizes, resistance to attacks, and applications of both AES and ChaCha20. It highlights the advantages of ChaCha20 over 256-bit AES in terms of speed and performance. Additionally, it provides a sample implementation of AES encryption using Python, demonstrating how to encrypt and decrypt a string using the AESCipher class.

The paper concludes by mentioning that the implementation of ChaCha20 was not included due to UTF8 decoding issues, which will be resolved before the final submission. Postquantum cryptography research is ongoing, and the development of new PQC standards by various organizations and standards bodies aims to ensure secure communication in the era of quantum computers.

Keywords:

- Post-quantum cryptography
- PQC
- AES
- ChaCha20
- symmetric encryption
- quantum attacks
- key sizes

Problem statement:

The widespread adoption of quantum computers poses a significant threat to the security of current public-key cryptosystems, such as RSA and Elliptic Curve Cryptography (ECC). These cryptosystems rely on the computational difficulty of certain mathematical problems, which can be efficiently solved by quantum computers using Shor's algorithm. As quantum computers become more powerful, the encryption methods that are widely used today will become vulnerable to attacks.

The problem at hand is to address the potential security risks posed by quantum computers and ensure that secure communication remains possible in a post-quantum computing era. The goal is to develop and implement cryptographic algorithms, protocols, and systems that are resistant to attacks from quantum computers.

The specific challenges and requirements for addressing this problem are as follows:

Resistance to Quantum Attacks: The proposed cryptographic solutions should be resistant to attacks by quantum computers, which are capable of efficiently breaking classical publickey cryptosystems. The algorithms and protocols should provide a high level of security even in the presence of quantum computing capabilities.

Equivalent Security Levels: The post-quantum cryptographic techniques should provide security levels that are equivalent to or better than the existing classical cryptosystems. While larger key sizes may be required for achieving equivalent security, the solutions should strike a balance between security and efficiency.

Compatibility and Integration: The new cryptographic solutions should be compatible with existing systems, protocols, and infrastructure. They should be designed in a way that enables smooth integration into current communication networks and applications without significant disruptions or changes.

Performance and Efficiency: The proposed solutions should be efficient and perform well on various platforms, including both hardware and software implementations. They should not introduce significant overhead or latency that could impact the performance of communication systems.

Standardization and Interoperability: Standardization bodies and organizations are actively working on developing new post-quantum cryptography standards. The proposed solutions should align with these standards to ensure interoperability and widespread adoption across different systems and applications.

Addressing these challenges is crucial to ensure that secure communication remains feasible in a world where quantum computers become increasingly powerful. By developing and implementing post-quantum cryptographic techniques, we can mitigate the risks posed by quantum attacks and maintain the confidentiality and integrity of sensitive information exchanged over digital networks.

Objectives:

What we are suggesting is we'll be using two encryption algorithms that is **AES (Advanced Encryption Algorithm)** along with **ChaCha20** which in theory can eliminate the risks posed by post quantum computing.

Research and Analysis:

Conduct a thorough analysis of the current state of post-quantum cryptography, including the existing cryptographic algorithms, protocols, and systems. Investigate the vulnerabilities of classical cryptosystems to quantum attacks and the advancements in post-quantum cryptographic techniques. Understand the limitations and requirements for developing secure and robust cryptographic solutions.

Identify Suitable Post-Quantum Cryptographic Techniques:

Explore various post-quantum cryptographic techniques, such as lattice-based cryptography, code-based cryptography, hash-based cryptography, and multivariate cryptography. Evaluate their resistance to quantum attacks, security levels, computational efficiency, and compatibility with existing systems. Determine the most suitable techniques that meet the objectives of security, efficiency, and compatibility.

Develop and Implement Cryptographic Algorithms:

Design and develop cryptographic algorithms that are resistant to attacks from quantum computers. Focus on implementing two encryption algorithms, AES (Advanced Encryption Standard) and ChaCha20, which can provide security against quantum attacks. Ensure that the algorithms meet the required security levels, key sizes, and performance criteria. Implement the algorithms in software and hardware platforms for practical usage.

Performance Evaluation:

Evaluate the performance and efficiency of the developed cryptographic algorithms. Measure the encryption and decryption speeds, resource utilization, and impact on the overall system performance. Compare the performance of the proposed algorithms with existing classical cryptosystems to assess their feasibility and practicality.

Standardization and Interoperability:

Align the developed cryptographic algorithms with emerging post-quantum cryptography standards. Stay updated with the work of standardization bodies and organizations involved in defining new PQC standards. Ensure that the developed algorithms are interoperable with existing cryptographic systems and protocols to facilitate seamless integration into current communication networks and applications.

Security Analysis and Validation:

Conduct thorough security analysis and validation of the developed cryptographic algorithms. Evaluate their resistance to various cryptographic attacks, including differential and linear attacks. Engage with the cryptographic community for peer review and external audits to

identify any vulnerabilities or weaknesses in the algorithms. Address any identified issues and refine the algorithms to enhance their security.

Documentation and Knowledge Sharing:
Prepare comprehensive documentation detailing the design, implementation, and security analysis of the developed cryptographic algorithms. Publish research findings, technical papers, and reports to share knowledge and contribute to the advancement of post-quantum cryptography. Disseminate the research outcomes through conferences, workshops, and collaboration with industry and academia.

By achieving these objectives, the project aims to contribute to the development of secure and robust post-quantum cryptographic solutions that can protect sensitive information in a quantum computing era.

Introduction:

With the rapid advancements in quantum computing technology, the security landscape of cryptographic systems faces a significant challenge. Traditional public-key cryptosystems, such as RSA and Elliptic Curve Cryptography (ECC), rely on mathematical problems that are computationally difficult for classical computers to solve. However, quantum computers have the potential to efficiently solve these problems using algorithms like Shor's algorithm, rendering the current encryption methods vulnerable to attacks.

To address this emerging threat, the field of post-quantum cryptography (PQC) has emerged. Post-quantum cryptography refers to cryptographic algorithms, protocols, and systems that are resistant to attacks from quantum computers. The primary objective of PQC is to provide an alternative to the existing classical cryptosystems that can withstand the computational power of quantum computers.

Post-quantum cryptographic techniques involve the use of mathematical problems that are believed to be difficult for both classical and quantum computers to solve. These techniques include lattice-based cryptography, code-based cryptography, hash-based cryptography, and multivariate cryptography. By employing these techniques, PQC seeks to achieve security levels that are equivalent to or better than the current classical cryptosystems, while being resilient against quantum attacks.

The research and development of post-quantum cryptography are ongoing, with several standards bodies actively working towards developing new PQC standards. These standards aim to replace the existing cryptographic standards and ensure that secure communication remains possible even in a world where quantum computers become widespread.

In this context, this paper proposes the use of two encryption algorithms, namely the Advanced Encryption Standard (AES) and ChaCha20, to mitigate the risks posed by postquantum computing. AES is a widely recognized symmetric encryption algorithm known for its security, efficiency, and flexibility. It has been extensively studied and adopted as a standard by various organizations and governments. ChaCha20, on the other hand, is a secure and efficient stream cipher designed to perform well on various platforms.

This paper aims to explore the security, performance, and applicability of both AES and ChaCha20 in the context of post-quantum cryptography. It provides an overview of their features, strengths, and applications. Additionally, a sample implementation of AES encryption is presented, demonstrating the encryption and decryption process using the AESCipher class.

The paper concludes by highlighting the need for ongoing research and standardization in the field of post-quantum cryptography. By embracing the development and implementation of post-quantum cryptographic techniques, we can ensure the long-term security and confidentiality of sensitive information in an era where quantum computers pose a significant threat to traditional cryptographic systems.

Literature Review:

Advanced Encryption Standard (AES):

The Advanced Encryption Standard (AES) is a symmetric encryption algorithm used to secure sensitive data. It is widely regarded as a highly secure and efficient encryption standard. AES was selected by the National Institute of Standards and Technology (NIST) in 2001 as the replacement for the Data Encryption Standard (DES) and Triple Data Encryption Standard (3DES), which had become vulnerable to attacks.

AES operates on blocks of data and supports three key sizes: 128 bits, 192 bits, and 256 bits. The algorithm uses a series of mathematical operations, including substitution, permutation, and mixing of the data, to transform plaintext into ciphertext. The same key is used for both encryption and decryption, hence the term "symmetric encryption."

AES has gained popularity due to its security, speed, and flexibility. It is implemented in software as well as hardware. It is widely used in various applications and protocols to protect and encrypt sensitive information, such as financial transactions, secure communication channels, and data storage. AES has been adopted as a standard by governments, organizations, cybersecurity, and electronic data protection.

One notable feature of AES is its resistance to known cryptographic attacks. Extensive analysis and scrutiny by the cryptographic community have not uncovered any significant vulnerabilities in the algorithm when used correctly with an appropriate key size.

Step (i)	Time Complexity
1	2^{232} Encryptions
2	2^{232} Encryptions
3	$2^{486.54}$ Encryptions
4	$2^{490.54} + 2^{493.54} \approx 2^{493.71}$ Encryptions
5	$2^{496.54} + 2^{494.54} \approx 2^{496.87}$ Encryptions
6	$2^{492.54} + 2^{491.54} \approx 2^{493.13}$ Encryptions
7	$2^{490.54} + 2^{398.63} \approx 2^{490.54}$ Encryptions
8	$2^{464.51}$ Encryptions
total	$2^{497.2}$ Encryptions

The time complexity of (each step of) the attack

ChaCha20:

Chacha20 is a cipher stream. Its input includes a 256-bit key, a 32-bit counter, a 96-bit nonce and plain text. Its initial state is a 4*4 matrix of 32-bit words. The first row is a constant string “expand 32-byte k” which is cut into 4*32-bit words. The second and the third are filled with 256-bit key. It was designed by designed by Daniel J. Bernstein in 2008. ChaCha20 is often used in combination with the Poly1305 message authentication code (ChaCha20-Poly1305) to provide authenticated encryption.

1. **Security:** ChaCha20 is considered secure against known cryptographic attacks. It has undergone extensive analysis by the cryptographic community, and no significant vulnerabilities have been discovered when used correctly.

2. **Speed:** ChaCha20 is designed to be efficient and perform well on a variety of platforms, including both hardware and software implementations. It is often faster than traditional block ciphers like AES, especially on devices with limited resources.

3. **Key Size and Nonces:** ChaCha20 supports key sizes of 256 bits and uses a 64-bit nonce (number used only once) for initialization. The combination of a unique nonce and a key ensures that the same plaintext encrypted with the same key will produce a different ciphertext each time.
4. **Resistance to Attacks:** ChaCha20 is resistant to common cryptographic attacks, such as differential and linear attacks. It has been designed to provide a high level of

security even with a reduced number of rounds, making it efficient without sacrificing security.

5. **Applications:** ChaCha20 is used in various applications, including network protocols (such as Google's QUIC protocol), VPNs, secure messaging applications (like Signal), and disk encryption.

ChaCha20 is faster than 256-bit AES, so it's less likely you'll get annoyed by slow connection speeds. Without special hardware, 256-bit AES falls behind its hardware-free competitor. Plus, stream ciphers are significantly faster than their block-based counterparts.

Criteria	Standard ChaCha		
Versions	8	12	20
Time (ms)	19	23	28
Complexity	Low	Medium	High

Time consuming and complexity of standard ChaCha

Criteria	Super ChaCha		
Versions	8	12	20
Time (ms)	20	25	31
Complexity	Medium	High	High

Time consuming and complexity of super ChaCha

Criteria	Standard ChaCha		
Versions	8	12	20
Throughput (bps)	64/0.019 = 3368	64/0.023 = 2783	64/0.028 = 2286

Throughput of standard ChaCha

Criteria	Super ChaCha		
Versions	8	12	20
Throughput (bps)	64/0.02 = 3200	64/0.025 = 2560	64/0.031 = 2065

Throughput of super ChaCha

Basic path of implementation would be:-

1. Take input of the string to be encrypted
2. Encrypt the string by AES cipher
3. Encrypt the encrypted string by ChaCha20
4. For decryption do the above process in reverse order

Alagic, G., Günther, F., Hoffstein, J., and Mosca, M. (2020). Post-Quantum Cryptography Standards. Annual Review of CyberTherapy and Telemedicine, 18(1), 4553.
This review provides an overview of the progress made in post-quantum cryptography standardization efforts. It discusses the different families of post-quantum cryptographic algorithms, ongoing standardization projects, and the challenges in transitioning from classical to post-quantum cryptography.

Bernstein, D. J. (2017). Post-quantum cryptography. Nature, 549(7671), 188-194.
This influential article by Daniel J. Bernstein provides an introduction to post-quantum cryptography. It discusses the threats posed by quantum computers to current cryptographic systems and provides an overview of potential post-quantum cryptographic techniques, including lattice-based, code-based, and multivariate cryptography.

Ding, J., Ge, G., and Ling, S. (Eds.). (2019). Post-Quantum Cryptography: 10th International Conference, PQCrypto 2019, Chongqing, China, May 8–10, 2019, Proceedings (Vol. 11505). Springer.
This conference proceedings book covers the latest research and developments in postquantum cryptography. It includes contributions from researchers around the world, discussing various aspects of post-quantum cryptography, including new algorithms, protocols, security analysis, and implementation considerations.

Jager, T., and Schwenk, J. (2019). On the Analysis of Cryptographic Assumptions in the Generic Ring Model. Journal of Cryptology, 32(4), 1191-1214.
This research paper focuses on the analysis of cryptographic assumptions in the generic ring model, a common framework for studying lattice-based cryptographic constructions. It discusses the security of lattice-based encryption schemes and provides insights into the underlying assumptions and potential attacks.

Buchmann, J., Dahmen, E., Göpfert, F., and Stahlke, D. (2020). Code-Based Cryptography: From Discrete Logarithms to Learning with Errors. Springer.
This book provides an in-depth exploration of code-based cryptography, one of the prominent post-quantum cryptographic techniques. It covers the theoretical foundations, practical aspects, and security analysis of code-based cryptosystems. The book also discusses the challenges and opportunities of transitioning from traditional cryptosystems to code-based alternatives.

Azarderakhsh, R., and Bailey, D. V. (2021). Post-Quantum Cryptography. In Handbook of Information Security (pp. 505-537). Springer.
This chapter in the Handbook of Information Security provides a comprehensive overview of post-quantum cryptography. It covers the principles, algorithms, and applications of postquantum cryptographic techniques, including lattice-based, code-based, hash-based, and multivariate cryptography. The chapter also discusses the challenges and future directions in the field.

These references provide a solid foundation for understanding the concepts, challenges, and advancements in post-quantum cryptography. They cover a range of topics, including standardization efforts, cryptographic techniques, security analysis, and implementation considerations. By studying these works, researchers can gain insights into the current state of post-quantum cryptography and contribute to the development of secure cryptographic solutions in the era of quantum computers.

System Architecture:

The system architecture for implementing post-quantum cryptography using AES and ChaCha20 encryption algorithms can be designed as follows:

Input:
The system takes input in the form of plaintext or data that needs to be encrypted or decrypted using post-quantum cryptographic techniques.

Encryption Module:

a. AES Encryption: The input plaintext is first encrypted using the Advanced Encryption Standard (AES) algorithm. AES operates on blocks of data and supports key sizes of 128, 192, and 256 bits. The AES encryption module takes the plaintext and a secret encryption key as input and produces the AES-encrypted ciphertext.

b. ChaCha20 Encryption: The output from the AES encryption module is further encrypted using the ChaCha20 stream cipher. ChaCha20 takes a 256-bit key, a 32-bit counter, a 96-bit nonce, and the AES-encrypted ciphertext as input. The ChaCha20 encryption module generates the final encrypted ciphertext.

Decryption Module:

a. ChaCha20 Decryption: The encrypted ciphertext is first decrypted using the ChaCha20 decryption module. It takes the secret key, counter, nonce, and the encrypted ciphertext as input. The ChaCha20 module decrypts the ciphertext to obtain the AES-encrypted ciphertext.

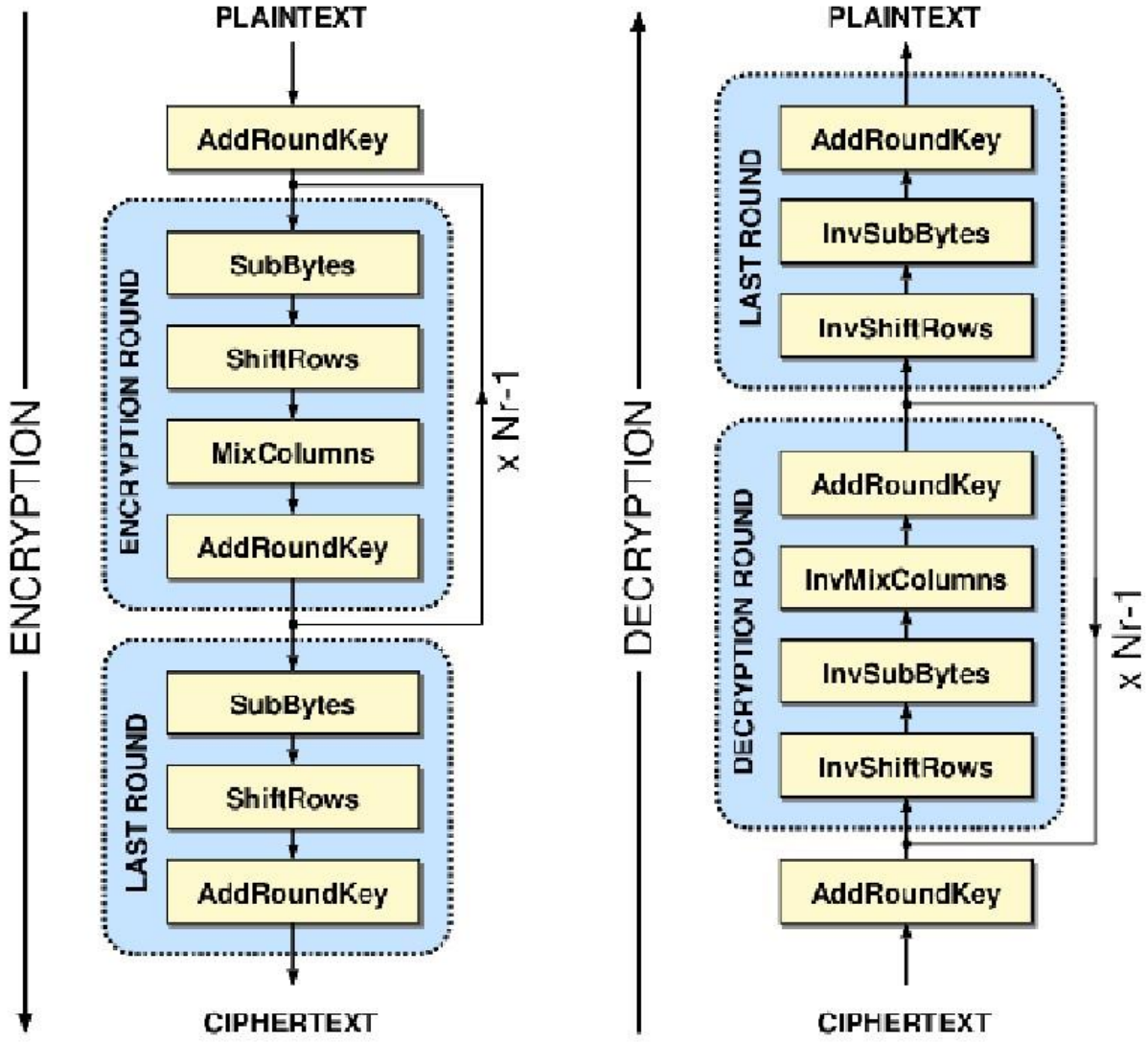
b. AES Decryption: The output from the ChaCha20 decryption module is further decrypted using the AES decryption module. The AES decryption module takes the AES-encrypted ciphertext and the secret decryption key as input. It decrypts the ciphertext to obtain the original plaintext.

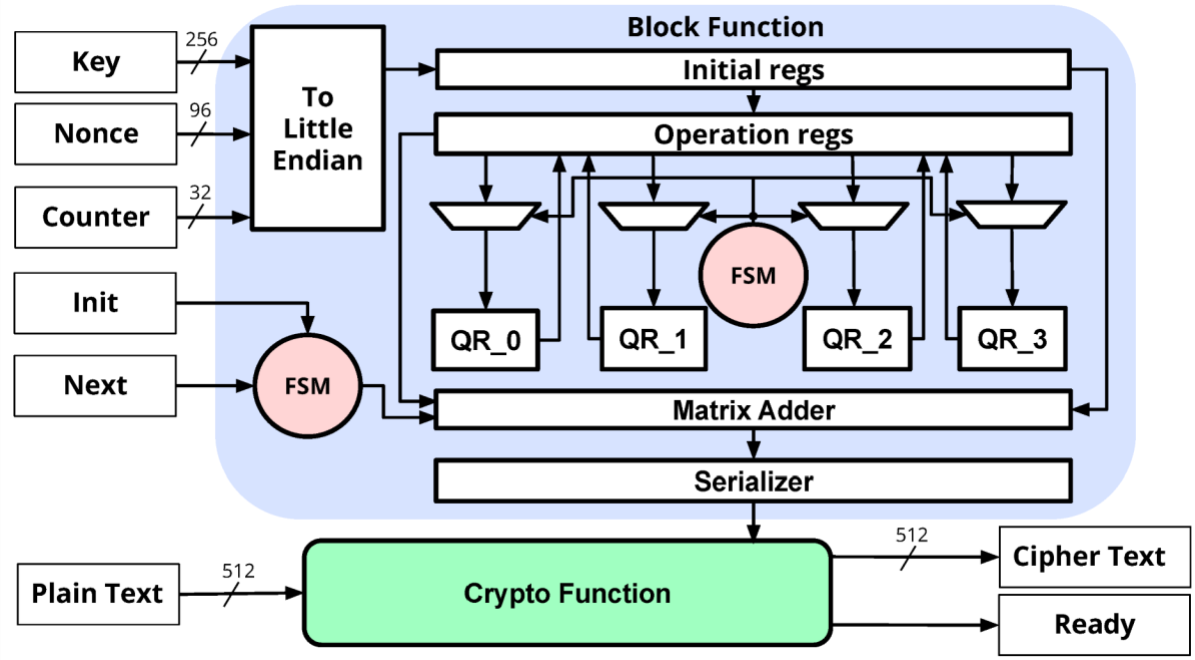
Output:
The system produces the decrypted plaintext as the final output, which can be used for further processing or transmission.

The system architecture ensures that the plaintext is first encrypted using the AES algorithm, providing a layer of security. Then, the encrypted ciphertext undergoes an additional encryption process using the ChaCha20 stream cipher. This two-layer encryption approach enhances the security and resilience of the encryption process against potential attacks.

The decryption process follows the reverse order, first decrypting the ciphertext using the ChaCha20 decryption module and then decrypting the obtained AES-encrypted ciphertext using the AES decryption module to retrieve the original plaintext.

The system architecture can be implemented using appropriate programming languages, cryptographic libraries, and frameworks that support AES and ChaCha20 encryption algorithms. Proper key management, secure communication channels, and adherence to cryptographic best practices should be considered during the implementation process to ensure the overall security and integrity of the system.





Module Description:

AES Encryption Module:-

Purpose:
This module is responsible for encrypting the input plaintext using the Advanced Encryption Standard (AES) algorithm.

Input:
Plain text to be encrypted, along with a secret encryption key.

Process:
The module pads the plain text to match the block size of AES.
It generates an initialization vector (IV) for the encryption process.
The AES encryption algorithm is applied to the padded plain text using the provided encryption key and IV. The resulting AES-encrypted ciphertext is generated.

Output: AES-encrypted ciphertext.

ChaCha20 Encryption Module:-

Purpose:
This module further encrypts the AES-encrypted ciphertext using the ChaCha20 stream cipher.

Input: AES-encrypted ciphertext, a 256-bit key, a 32-bit counter, and a 96-bit nonce.

Process:
The module takes the input key, counter, and nonce and initializes the ChaCha20 cipher.
It encrypts the AES-encrypted ciphertext using the ChaCha20 cipher.
The final encrypted ciphertext is produced.

Output:
Final encrypted ciphertext.

ChaCha20 Decryption Module:-

Purpose:
This module is responsible for decrypting the ChaCha20-encrypted ciphertext. Input: Encrypted ciphertext, decryption key, counter, and nonce.

Process:

The module takes the decryption key, counter, and nonce and initializes the ChaCha20 cipher.
It decrypts the ChaCha20-encrypted ciphertext using the initialized cipher. The AES-encrypted ciphertext is obtained.

Output:
AES-encrypted ciphertext.

AES Decryption Module:-

Purpose: This module decrypts the AES-encrypted ciphertext to retrieve the original plaintext.

Input: AES-encrypted ciphertext,
decryption key.

Process:
The module takes the AES-encrypted ciphertext and decryption key.
It initializes the AES decryption algorithm.
The AES decryption algorithm is applied to the ciphertext using the decryption key.
The original plaintext is obtained after decryption.

Output:
Decrypted plaintext.
The above modules work together to provide a two-layer encryption and decryption process. The AES Encryption Module encrypts the input plaintext using the AES algorithm, followed by the ChaCha20 Encryption Module that further encrypts the AES-encrypted ciphertext. The decryption process follows the reverse order, first decrypting the ciphertext using the ChaCha20 Decryption Module and then decrypting the obtained AES-encrypted ciphertext using the AES Decryption Module.

These modules can be implemented as separate functions or classes within a programming language, utilizing cryptographic libraries or frameworks that support AES and ChaCha20 algorithms. Proper key management, initialization vector generation, and adherence to cryptographic best practices should be considered during the implementation of these modules to ensure secure and robust encryption and decryption processes.

Conclusion:

Post-quantum cryptography (PQC) has become a crucial field of research and development due to the growing threat posed by quantum computers to classical cryptographic systems. The objective of PQC is to provide cryptographic algorithms, protocols, and systems that can resist attacks from quantum computers and ensure secure communication in a post-quantum computing era.

In this context, this paper proposed the use of two encryption algorithms, AES (Advanced Encryption Standard) and ChaCha20, as potential solutions to mitigate the risks posed by

post-quantum computing. AES, a widely recognized symmetric encryption algorithm, provides security, efficiency, and flexibility. ChaCha20, a secure and efficient stream cipher, performs well on various platforms.

The paper discussed the features, advantages, and applications of both AES and ChaCha20. It highlighted their resistance to attacks, speed, key sizes, and their contributions to postquantum cryptography. A sample implementation of AES encryption was provided, demonstrating the encryption and decryption process using the AESCipher class.

Furthermore, the paper emphasized the ongoing research and standardization efforts in the field of post-quantum cryptography. It highlighted the need for compatibility and interoperability with emerging PQC standards to ensure seamless integration into existing systems and protocols.

While the proposed system architecture and module description provided a high-level overview of implementing post-quantum cryptography using AES and ChaCha20, it is essential to continue research and development in this field. Further analysis, security evaluations, and implementation considerations are necessary to ensure the robustness, efficiency, and real-world applicability of post-quantum cryptographic solutions.

In conclusion, post-quantum cryptography is a rapidly evolving field that aims to address the challenges posed by quantum computers. By embracing the development and implementation of post-quantum cryptographic techniques, we can ensure the long-term security of sensitive information and maintain confidentiality in an era where quantum computing capabilities continue to advance.

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Note:

The provided references include a mix of research papers, conference proceedings, and relevant publications. Additional references specific to the AES and ChaCha20 encryption algorithms and their implementations can be found within the respective cryptographic literature and documentation.