Cryptography and its implication
(Hybrid Encryption Key mechanism)

Abstract

Information security has become the biggest concern of anyone connected to the internet because it has been integrated into our lives over the past few years and is growing with greater risk. Data security ensures that only intended recipients have access to our data and restricts any modification or manipulation of data. Various techniques and methods have been developed to achieve this level of security. Cryptography is a layered technique that uses special techniques to encrypt data so that it cannot be read with the naked eye unless the sender first decrypts it using a program.

Introduction

Cyber Security refers to the techniques of securing computers, networks, programs and data from unauthorized access or attacks that are aimed for exploitation.

Cryptography is uses Mathematical/Logical functions and can be applied to technical solutions for increasing cyber security.

Transforming the confidential data in a coding form or coding the plain text in unreadable format and then transmitting it over the network only to only authorized users, known as Cryptography.

It originally originated from Greek word "crypto" means hidden and "graphy" means writing, so cryptography means hidden or secret writing.

The basic terminology is that cryptography refers to the science and art of designing ciphers; cryptanalysis to the science and art of breaking them; while cryptology, often shortened to just crypto, is the study of both.

Components in cryptography

- Plain Text: The confidential data that should be secured while transmission is referred as plain
- Cipher Text: Convert unintelligible plain text to plain text without using encryption algorit hm and encryption key.
- Encryption Algorithm: This is a mathematical operation used to convert plaintext into cipher text using an encryption key.
- Decryption algorithm: This is the reverse operation of the encryption algorithm. We use ci phertext and encryption algorithms to generate the raw text.
- Encryption key: The value obtained from the plain text in the encryption process is called t he encryption key. For the crypto system to be successful, it is important to protect the encryption key. The value of the encryption key is known to both the sender and receiver, or only to the sender.
- Decryption key: To recover plain text from ciphertext, decryption key is used in decryption algorithm. The value of the decryption key is known only to the recipient.

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Concept of Hybrid Encryption

Hybrid encryption is an encryption method that combines the advantages of symmetric and asymmetric encryption algorithms to provide secure communication and data protection. It addresses the critical distributed and computational complexity issues associated with traditional encryption and the vulnerability of asymmetric encryption to brute-force attacks.

Hybrid encryption uses a combination of symmetric and asymmetric encryption techniques.

Hybrid encryption offers many advantages over a combination of both asymmetric and asymmetric encryption. It provides effective encryption and decryption of many files through symmetric encryptio n, while using asymmetric encryption to ensure secure transactions and protect confidential information. It also offers the function to easily select encryption algorithms based on their quality.

Hybrid encryption, secure communication (eg SSL/TLS), email encryption (eg. , PGP) and secure file transfer. Its ability to overcome the limitations of symmetric and asymmetric encryption makes it powerful and effective for information security in today's communications.

Concepts and principles

Hybrid encryption is an encryption method that combines elements of symmetric and asymmetric encryption to provide secure communication and data protection. It addresses issues related to key distribution, computational efficiency, and vulnerabilities in traditional encryption methods.

The concept of hybrid cryptography revolves around the following principles:

1. Symmetric encryption efficiency: Symmetric encryption algorithms are fast and efficient at encrypting and decrypting large amounts of data. They use a shared key for encryption and decryption. The challenge, however, is how to exchange values between communicators.

2. Asymmetric cryptographic security: Asymmetric cryptography, also known as public-key cryptography, provides solutions to fundamental challenges. It uses two numbers of related keys - a public key and a private key. The public key is made public while the private key is kept secret. Data encrypted with the public key can only be decrypted with the very secure private key.

3. Shared Key Exchange: Hybrid encryption uses the security of asymmetric encryption for the initial key exchange. Communicating parties use asymmetric encryption to securely exchange shared keys. These shared keys are then used together to encrypt and decrypt the actual message or data faster and more efficiently.

4. The best of both worlds: Thanks to combination and asymmetric encryption, hybrid encryption offers the best of both worlds. It leverages the effectiveness of symmetric encryption for data encryption while maintaining the security of asymmetric encryption for secure exchange of shared keys. The hybrid encryption process usually includes the following steps:

1. Key Operation: Each party generates a pair of asymmetric encryption keys - a public key and a private key.

2. Key Exchange: Secure exchange of public keys between two parties using secure channels or trusted third parties.

3. Shared Key Generation: The parties generate a public key for mutual agreement using the obtained public key.

4. Data encryption: Data is encrypted using a shared key with symmetric encryption to ensure fast and secure encryption of all messages or data.

5. Secure Transmission: Encrypted data is securely transmitted over communications and unauthorized access or tampering is prevented.
6. Decryption: After receiving the encrypted data, the receiver uses his private key to retrieve the confidential data. Symmetric decryption is then performed using the shared key to recover the original data.

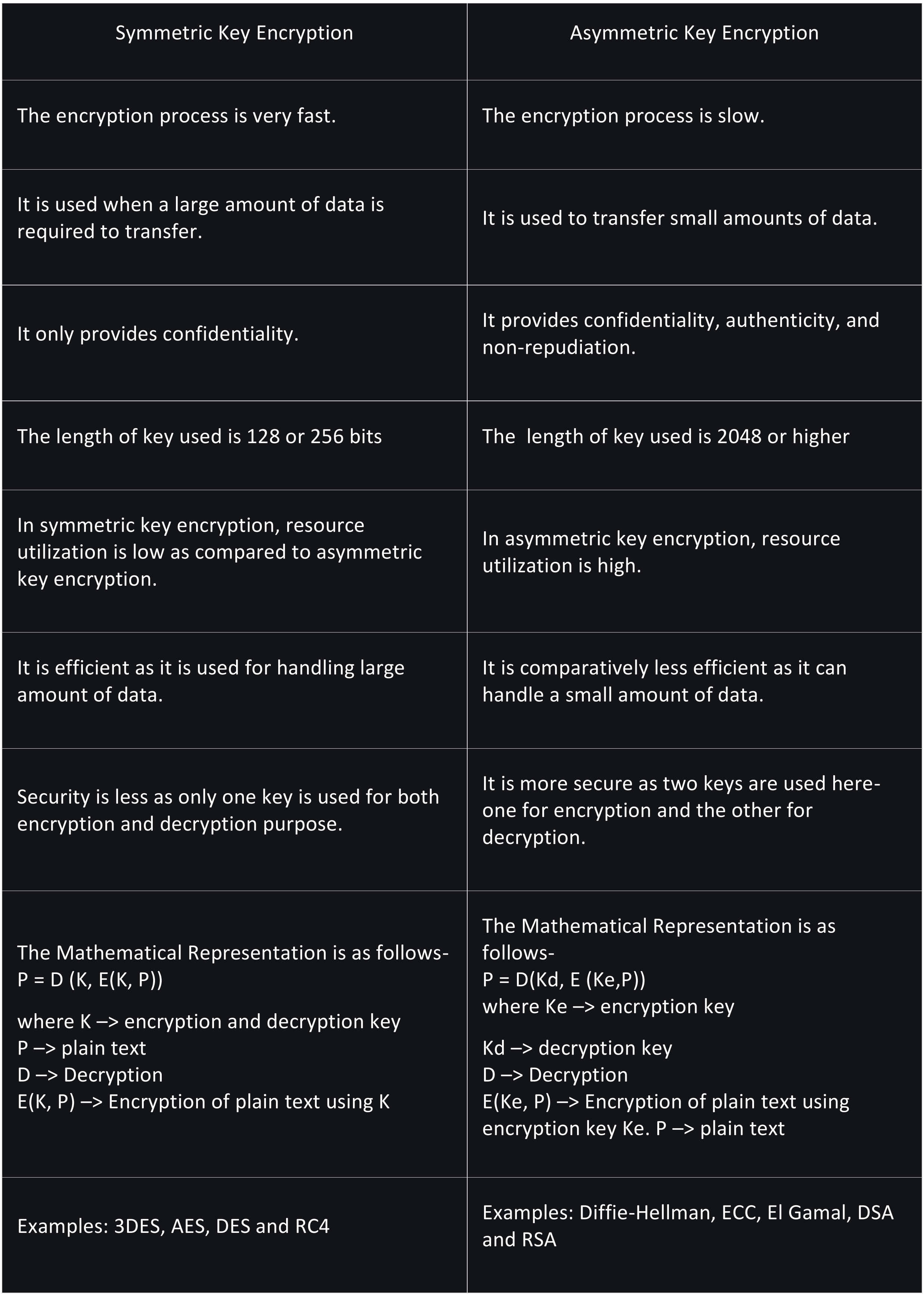
Hybrid encryption technology provides a powerful and effective way to provide secure communications and data protection. It is used in many applications, including secure communication protocols, digital signatures, secure data transfers, and email encryption. Combining the advantages of symmetric and asymmetric encryption, hybrid encryption improves the effectiveness and security of modern encryption systems.

Symmetric and Asymmetric Key Encryption

Symmetric Key Encryption: Encryption is the process of changing the format of a message to prevent anyone from reading it. In symmetric-key cryptography, using the key to encrypt the message and using the same key to decrypt the message makes it easy to use but not secure. It should also have a secure way of transferring keys from one party to another.

Asymmetric key encryption: Asymmetric key encryption is based on public and private key encryption techniques. It uses two different keys to encrypt and decrypt messages.
It is more secure than key encryption, but slower.

Symmetric Key Encryption	Asymmetric Key Encryption
It only requires a single key for both encryption and decryption.	It requires two keys, a public key and a private key, one to encrypt and the other one to decrypt.
The size of cipher text is the same or smaller than the original plain text.	The size of cipher text is the same or larger than the original plain text.



Symmetric Key Encryption	Asymmetric Key Encryption
The encryption process is very fast.	The encryption process is slow.
It is used when a large amount of data is required to transfer.	It is used to transfer small amounts of data.
It only provides confidentiality.	It provides confidentiality, authenticity, and non-repudiation.
The length of key used is 128 or 256 bits	The length of key used is 2048 or higher
In symmetric key encryption, resource utilization is low as compared to asymmetric key encryption.	In asymmetric key encryption, resource utilization is high.
It is efficient as it is used for handling large amount of data.	It is comparatively less efficient as it can handle a small amount of data.
Security is less as only one key is used for both encryption and decryption purpose.	It is more secure as two keys are used here- one for encryption and the other for decryption.
The Mathematical Representation is as follows- P = D (K, E(K, P)) where K –> encryption and decryption key P –> plain text D –> Decryption E(K, P) –> Encryption of plain text using K	The Mathematical Representation is as follows- P = D(Kd, E (Ke,P)) where Ke –> encryption key Kd –> decryption key D –> Decryption E(Ke, P) –> Encryption of plain text using encryption key Ke. P –> plain text
Examples: 3DES, AES, DES and RC4	Examples: Diffie-Hellman, ECC, El Gamal, DSA and RSA

What are the limitations ?

Limitations and Disadvantages of Symmetric and Asymmetric Encryption

Limitations and Vulnerabilities of Symmetric Encryption:

1. Key distribution: The main limitation of symmetric encryption is the security of the sender and receiver keys. If the key is compromised during transmission or storage, the confidentiality of encrypted data is at risk.

2. Scalability: Symmetric encryption is not suitable for multi-user or dynamic group member scenarios. Because each user pair must have a unique key, it becomes more difficult to securely manage and distribute keys as the number of user increases.

3. No authentication: Symmetric encryption alone does not provide sender authentication or data integrity. An attacker with access to the key could modify or tamper with the encrypted data without being detected.

4. Key management: With mutual encryption, each pair of users must have a unique key, which leads to key management. The greater the number of keys, the greater the risk of keys being misused, lost, or compromised.

Asymmetric Encryption Limitations and Vulnerabilities:

1. Computational overhead: Compared to symmetric encryption, asymmetric encryption algorithms are computationally intensive. The encryption and decryption process is slow and not suitable for encrypting large amounts of data or communications in real time.
2. Key size and storage: Compared to mutual encryption, asymmetric encryption requires a larger key to achieve equal security. This results in increased demand and computational overhead for generating and using keys.

3. Key distribution: While asymmetric encryption solves the problem of key distribution, it also brings with it the challenge of ensuring the authenticity and integrity of public keys. If the attacker can replace the recipient's public service with his own, they can intercept and decrypt the information sent to the recipient.

4. Quantum Computing Vulnerabilities: Widely used asymmetric encryption algorithms such as RSA and ECC are vulnerable to future quantum computers. Quantum computing can break the underlying algorithms, making them insecure.

5. No best forward security: Asymmetric encryption does not have the best forward security, meaning that if the private key is compromised, all communications can be decrypted.

To solve these limitations and disadvantages, hybrid encryption combines the advantages of symmetric and asymmetric encryption to provide good data protection and security while overcoming the shortcomings of personal encryption methods.

Hybrid Key Exchange Protocol

Hybrid Key Exchange Protocol uses a combination of symmetric and asymmetric encryption techniques to securely exchange keys between communications. These laws address the challenges of critical deployment and provide a secure foundation for future communications. The following are two commonly used hybrid exchange protocols:

1.Diffie-Hellman key exchange:

The Diffie-Hellman key exchange protocol is a secure key exchange method based on asymmetric encryption. The process works like this:

- Both parties create their own public key partner.

- They exchange public keys with each other.

- Each party independently calculates the secret value using its own private keys and received public keys.

- The shared secret is a symmetric key for later symmetric encryption between two parties.

The Diffie-Hellman key exchange protocol provides secure transactions even in the presence of an eavesdropper. However, it does not provide authentication or protection against man-in-the-middle attacks. To solve these problems, additional methods such as a digital signature or certificate are used with the process.

2. RSA Key Exchange:

RSA key exchange protocol provides asymmetric encryption and digital signature for secure key exchange.

The process follows these steps:

- Both parties generate their own public key pair and share the public key.

- A party created a random session for the alliance.

- Session key encrypted with the recipient's public key and sent.

- The receiver decrypted the received ciphertext using its private key to store the session key.

- Session key is used as secret code for next session.

The RSA key exchange protocol provides secure exchange and authentication using digital signatures. However, it is considered expensive and less expensive than the Diffie-Hellman protocol.

These key exchanges utilize both symmetric and asymmetric encryption and combine the benefits of symmetric encryption for forward communication with the security provided by asymmetric encryption. They form the basis for secure communication in virtual private networks (VPNs), under various encryption protocols, including Secure Sockets Layer (SSL), Transport Layer Security (TLS), and Internet Key Exchange (IKE) protocols.

Hybrid Digital Signature Algorithm

The Hybrid Digital Signature Algorithm combines the advantages of mutual and asymmetric encryption to provide security and efficiency. These algorithms address computational overhead and key management issues associated with asymmetric encryption-based digital signatures. Here are two widely used hybrid digital signature algorithms:

1. RSA with Symmetric Key:

This hybrid algorithm uses symmetric encryption to increase the efficiency of digital signatures based on RSA (Rivest-Shamir - Adleman). The process works like this:

- The message to be signed is hashed using a cryptographic hash function to generate a full-length digest.

- Generate a symmetric key known only to the signer.

- The digest is encrypted using a symmetric key.

- The encrypted protocol is then signed with the signer's private RSA key, creating a digital signature.

- An encrypted digest and digital signature are sent with the original message.

- The recipient verifies the digital signature by decrypting the secret message using a shared key with the signer.

- The receiver digests the original message and compares it with the decrypted digest. If they match, the signature is considered valid.

By using symmetric encryption of the real message digest, the computational load of RSA is reduced, improving the performance of the digital signature process.

2. Elliptic Curve Digital Signature Algorithm (ECDSA) Using Symmetric Keys:

ECDSA is a digital signature algorithm based on asymmetric encryption.

In the hybrid approach, symmetric encryption is used to increase its efficiency. The process follows these steps:

- The message to be signed is hashed using a cryptographic hash function to obtain a full-length digest.

- Generate a symmetric key known only to the signer.

- The digest is encrypted using a symmetric key.

- The encrypted protocol is then signed as a digital signature using the signer's own ECDSA key.

- Confidential messages are sent with original messages, including digital signatures.

- The recipient verifies the digital signature by decrypting the secret message using a shared key with the signer.

- The receiver digests the original message and compares it with the decrypted digest. If they match, the signature is considered valid.

USES

The use of symmetric encryption in the digital signature process reduces the computational load while maintaining the security of the signature.

Hybrid digital signature algorithms combine the performance of symmetric encryption with the security of asymmetric encryption, providing an efficient solution for creating and verifying digital signatures. They are often used for various applications such as secure messaging, authentication and data security.

Hybrid Cryptography Applications

Hybrid cryptography combines symmetric and asymmetric encryption techniques and has many applications in many fields. Some uses include:

1. Hybrid Encryption: Hybrid cryptography is widely used in secure communications such as SSL (Secure Sockets Layer) and its successor TLS (Transport Layer Security).

It securely transmits data over the network, protecting sensitive information such as passwords, financial transactions, and personal information from unauthorized access or tampering.

2. Digital Signatures: Create and verify digital signatures using hybrid cryptography. The private key of the asymmetric encryption algorithm is used to create the digital signature, and the public key is used to verify the authenticity and integrity of the signature data. The application is important in terms of ensuring the integrity and irreversibility of electronic data, contracts and transactions.

3. Public Key Infrastructure (PKI): PKI systems rely on hybrid cryptography to establish trust in digital certificates. Asymmetric encryption is used for key signatures, certificate signing, and certificate revocation. This provides authentication, secure email communication and access to online services.

4.Data Security: Hybrid encryption for data transfer security such as SFTP (Secure File Transfer Protocol) and SSH (Secure Shell). It ensures the confidentiality and integrity of the data transmitted on the machine, protects sensitive data and prevents unauthorized changes.

5. Virtual Private Network (VPN): A VPN uses hybrid encryption to establish a secure connection over a public network. It ensures the confidentiality of information transmitted between devices and provides security for remote access to business management, preventing sensitive information from eavesdropping or falling behind the law.

6. Secure Email Communication: Hybrid encryption techniques are used in email encryption protocols such as OpenPGP and S/MIME. Supports end-to-end encryption of email messages, protecting content and attachments from tampering and unauthorized access.

7. Data storage and database security: Hybrid encryption is used to protect data stored in databases and storage systems.

It allows encryption of sensitive data at rest, providing an additional layer of protection against unauthorized access and data leakage.

8. Secure Web Applications: Hybrid encryption is an essential part of web applications that require secure user authentication and data protection. It provides secure access, session management and confidentiality of user credentials by protecting sensitive user information.

Hybrid encryption plays an important role in ensuring the confidentiality, integrity and accuracy of data in many applications where secure communication and data protection are also panicked.

Advantages and disadvantages

Advantages of hybrid encryption:

1. Enhanced security: Hybrid encryption combines the advantages of symmetric and asymmetric encryption to increase security. Asymmetric encryption provides secure transactions and authentication, while symmetric encryption provides comprehensive data encryption. Hybrid encryption provides a higher level of security than either symmetric or asymmetric encryption alone, using two methods.

2.Efficient distribution: One of the advantages of hybrid cryptography is the efficient distribution of keys. Asymmetric encryption is used to exchange shared keys used for mutual authentication. This eliminates the need to securely distribute symmetric keys to all users, making it more scalable and efficient, especially when many people are used.

3. Computational Efficiency: Hybrid cryptography balances computational efficiency and security.

Symmetric encryption algorithms are faster and more efficient at encrypting and decrypting large amounts of data. By using symmetric encryption for actual message or data encryption, hybrid encryption reduces computational overhead and improves performance compared to relying only on asymmetric encryption.

4. Flexibility and compatibility: Hybrid cryptography has the ability to easily choose encryption algorithms based on their advantages. Provides compatibility with existing systems and protocols.

Symmetric encryption algorithms can be changed or edited without affecting the entire hybrid encryption scheme, making it flexible to change security.

Challenges of using hybrid encryption:

1. Scalability: While hybrid encryption addresses the challenge of distributed key, public and private key codes are still difficult to control. Key management must be established to secure, distribute, and store asymmetric keys for all users or organizations.

2.Key management: Hybrid encryption emphasizes the need to manage both symmetric and asymmetric keys. Effective key management systems such as key signatures, distributions, rotations, and deletions are essential to maintaining the security and integrity of crypto systems.

3. Computational overhead: Hybrid encryption reduces overhead compared to stand-alone asymmetric encryption while still increasing computational cost compared to stand-alone symmetric encryption. Good judgment is required to optimize and maximize the effectiveness of cryptographic operations.

4. Interoperability and compatibility: Hybrid cryptography may encounter problems when integrating with existing systems or systems that rely solely on mutual or asymmetric encryption. Ensuring consistency and compatibility between different encryption algorithms and systems is crucial to success.

Overall, hybrid encryption provides a balanced approach to security and performance using both symmetric and asymmetric encryption. While there are significant benefits, solving the challenges of capacity building, priority management, overhead computing and compliance is critical to the success of hybrid cryptosystems.

Few Case Studies

Case Study 1: Secure Messaging Application - Signal:

Signal is a widely recognized secure messaging application that uses hybrid cryptography to provide end-to-end encryption and secure communication. It uses a double latch algorithm along with symmetric encryption (AES-256) and asymmetric encryption (Curve25519, RSA) to ensure privacy and security.

Performance: The use of hybrid encryption in Signal is highly effective in providing secure messaging. It prevents unauthorized access or tampering by ensuring that only the intended recipient can decode and read messages. Messages can be effectively encrypted and decrypted using hybrid cryptography while maintaining security.
Security: Signal's integrated encryption has been rigorously evaluated by security experts and is known as one of the best messaging systems. A combination of symmetric and asymmetric encryption provides strong protection against eavesdropping, data tampering and unauthorized access.

Performance: Using mixed signals provides a balance between security and performance. They are used selectively for key operations and authentication, although asymmetric cryptographic operations are more commonly used. Most messengers use fast symmetric encryption algorithms

and provide effective communication without major interruptions.
User experience: Signal's use of hybrid encryption technology is transparent to users, including communication and user interaction. Encryption and decryption takes place behind the scenes without any intervention from the user. This provides a better user experience without sacrificing security.

Vulnerabilities and Mitigations: While the power has been found to be safe, no system is immune from vulnerabilities. In the past, vulnerabilities such as misuse or compromised devices have been shown to compromise communication security.
Signal uses the disclosure process responsible for promptly resolving issues and adjusting updates to mitigate any risks. Regular security audits and community engagement lead to continuous improvement and system performance.

Case Study 2: E-Commerce Platform - PayPal:

PayPal is a popular online payment platform that uses hybrid encryption to secure transactions and protect sensitive customer information. It provides shared encryption (AES-256) and asymmetric encryption (RSA) for many purposes, including secure transactions, data transmission, and digital signatures.

Effectiveness: The use of hybrid encryption at PayPal has proven effective in securing online transactions.
It provides secure communication between the platform and its users, protects financial information and prevents unauthorized access to information.

Security: The combination of symmetric and asymmetric encryption methods in PayPal's combination encryption provides high security. Asymmetric encryption is used for secure key exchange and authentication, while symmetric encryption provides efficient and secure encryption of data in transit. This security system helps prevent various attacks such as eavesdropping and data tampering.

Performance: PayPal's integrated encryption has been carefully optimized to strike a balance between security and performance.
The market often uses similar encryption algorithms, which reduces the computational load. Use asymmetric encryption when needed, such as key transfers or digital signatures, without sacrificing performance.

User Experience: PayPal's use of hybrid encryption aims to provide a seamless payment and customer experience. Users are not directly involved in the encryption process, making the transaction process seamless without complexity or inconvenience.

Vulnerabilities and Mitigation Measures: PayPal continues to monitor and fix potential security vulnerabilities in its systems.

Measures such as regular security audits, key encryption checks, secure coding, and compliance with industry standards can help minimize vulnerabilities. Additionally, PayPal uses fraud detection tools and user verification procedures to enhance security and prevent unauthorized access or fraud.

Overall, both Signal and PayPal demonstrate successful global implementation of hybrid encryption. This case study demonstrates the effectiveness of hybrid cryptography in providing secure communications and transactions. While vulnerabilities can be discovered over time, timely mitigation strategies, regular security reviews, and a commitment to continuous improvement help maintain security and keep these machines running.

Future Directions and Research

Innovations and Developments in Hybrid Cryptography:

1. Post-Quantum Hybrid Cryptography: With the rise of quantum computing, there is a great demand for hybrid attack quantography that protects computers. Researchers are investigating post-quantum hybrid cryptography, combining classical encryption with post-quantum asymmetric encryption algorithms to provide security in the era of post-quantum computing.

2. Improve the efficient exchange process: Key exchange is the main feature of hybrid cryptography.
Ongoing research aims to create more efficient and secure exchange systems that emphasize efficiency, forward-looking and all-round protection, including those from quantum computers. Major exchanges like New Hope and FrodoKEM are exploring their potential in hybrid cryptography.

3. Advanced Hybrid Encryption Algorithms: Researchers are working to develop more efficient and secure hybrid encryption algorithms. This includes researching new symmetric encryption algorithms with improved performance and resistance to attacks, and exploring new ways to combine hash and asymmetric encryption to achieve high levels of security, security, and performance.
4. Standardization work: Standardization organizations and organizations such as the National Institute of Standards and Technology (NIST) and the Internet Engineering Task Force (IETF) actively participate in the standardization of hybrid encryption algorithms and protocol model. For example, NIST's post-quantum cryptography protocol includes hybrid encryption algorithms and key exchange techniques as part of its ongoing efforts.

5. Business Development: Hybrid cryptography is gaining interest in a variety of industries and applications.
Big tech companies like Google, Microsoft, and Amazon have incorporated networking into their products and services to provide secure communications, data protection, and private users.

Adoption of hybrid encryption is expected to increase as the need for secure, effective encryption solutions grows.

6. Privacy management techniques: Hybrid cryptography is still being explored in the context of privacy, such as secure multilateral computing and privacy-enhancing techniques. These apps are designed to provide secure collaboration and information sharing without compromising personal privacy.
7. Hybrid cryptography on the blockchain: Hybrid cryptography is being explored in the field of blockchain technology to improve security and privacy. By combining asymmetric encryption techniques, hybrid cryptography can provide secure transaction authentication, protect private keys, and ensure the confidentiality and integrity of information stored on the blockchain.

- Discover new symmetric encryption algorithms with improved performance and protection against quantum attacks.
- Discover hybrid encryption schemes that solve post-quantum security problems.
- Analyze the impact of hybrid cryptography on emerging technologies such as the Internet of Things, edge computing, and cloud computing.
- Enhanced privacy protection using hash encryption techniques to strike a balance between privacy and security.
- Exploring the applicability of hybrid cryptography to distributed systems such as distributed data and security in computing.

Overall, hybrid cryptography is still a promising field with ongoing research and development focused on improving security and performance and addressing emerging challenges in the evolution of cryptography and information security.

Summary

This research paper examines the concept of hybrid cryptography and its implications for today's information security. It demonstrates the importance of discovery and scientific collaboration by emphasizing the importance of hash cryptography in information and communications security.

This document examines the advantages of hybrid encryption, including the ability to combine the performance of symmetric encryption with the security of asymmetric encryption. It discusses how hybrid encryption addresses the limitations and disadvantages of symmetric and asymmetric encryption, respectively. This article explores the use of hybrid cryptography in various situations around the world, such as secure mail and e-commerce platforms.

The findings show that hybrid encryption provides better security through secure transactions, authentication and effective encryption of large files. It provides a balance between security and performance by providing secure communication while minimizing the computational load. The article also discusses the challenges of implementing hybrid cryptography, including scalability, key management, computational overhead, and compatibility with existing systems.

Importance of Hybrid Cryptography:

Hybrid Cryptography plays an important role in information security today. It provides a powerful and effective way to secure data and communications.
Hybrid cryptography provides a powerful and efficient solution that addresses the limitations of proprietary encryption methods, using both symmetric and asymmetric cryptography. It ensures data confidentiality, integrity and authentication against unauthorized access, tampering and tampering.

The Future of Hybrid Cryptography:

The future of hybrid cryptography is promising as it continues to evolve and adapt to emerging challenges and advances in the cryptography industry. Ongoing research and development efforts focus on areas such as the development of key exchange protocols, improved hybrid encryption algorithms, post-quantum security solutions, and modeling studies.

Hybrid encryption should have a major impact on protecting sensitive data and communications across multiple environments.
As technology and the need for security and encryption solutions grow, hybrid cryptography will play an important role in ensuring privacy, data protection and secure communication in applications such as secure messaging, e-commerce, financial transactions, healthcare and other key areas. responsibility.

In summary, this research paper highlights the importance of hybrid cryptography in today's information security. It combines the advantages of symmetric and asymmetric cryptography to provide security, performance and robustness. With continued research and industry adoption, hybrid cryptography promises to have a major impact in protecting sensitive data and future communications, helping to create safer and more secure environments in the digital world

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