A PROPOSED DESIGN AND IMPLEMENTATION OF A DECENTRALIZED MESSAGING APPLICATION USING BLOCKCHAIN TECHNOLOGY

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report titled "**A PROPOSED DESIGN AND IMPLEMENTATION OF A DECENTRALIZED MESSAGING APPLICATION USING BLOCKCHAIN TECHNOLOGY**" is the Bonafide work of "**Durgesh R. Potukuchi(23MEI10046), Yash Kumar Khaitan(23MEI10050), Jishan Ashraf(23MEI10015), Uday Sarvaiya (23MEI10059), Dev Soni(23MEI10066)"** who carried out the project work under my supervision. Certified further that to the best of my knowledge the work reported at this time does not form any other research/project work based on which a degree or award was conferred on an earlier occasion on this or any other candidate.

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LIST OF ABBREVATIONS

Project-Specific Abbreviations:

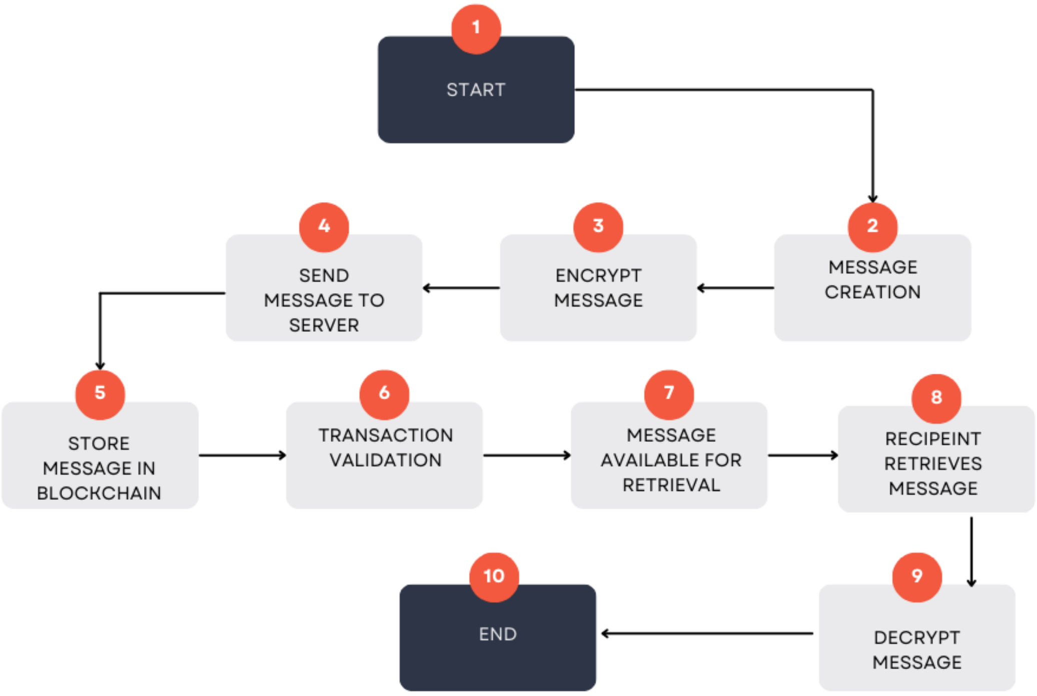
1. **RSA - Rivest-Shamir-Adleman** (Public key cryptosystem used for encrypting and decrypting messages)
2. **PKI - Public Key Infrastructure** (A framework for managing public and private keys)
3. **JSON - JavaScript Object Notation** (Used for serializing data between client and server)
4. **IP - Internet Protocol** (Used for client-server communication)
5. **AES - Advanced Encryption Standard** (While not explicitly used in your project, this might be relevant for future encryption extensions)
6. **CLI - Command Line Interface** (Used for user input in your messaging system)
7. **TCP - Transmission Control Protocol** (Used for socket-based communication between the client and server)
8. **PKCS1 - Public Key Cryptography Standards** (Format for saving and loading public/private RSA keys)
9. **SHA - Secure Hash Algorithm** (Used in blockchain for creating block hashes)

Blockchain-related Abbreviations:

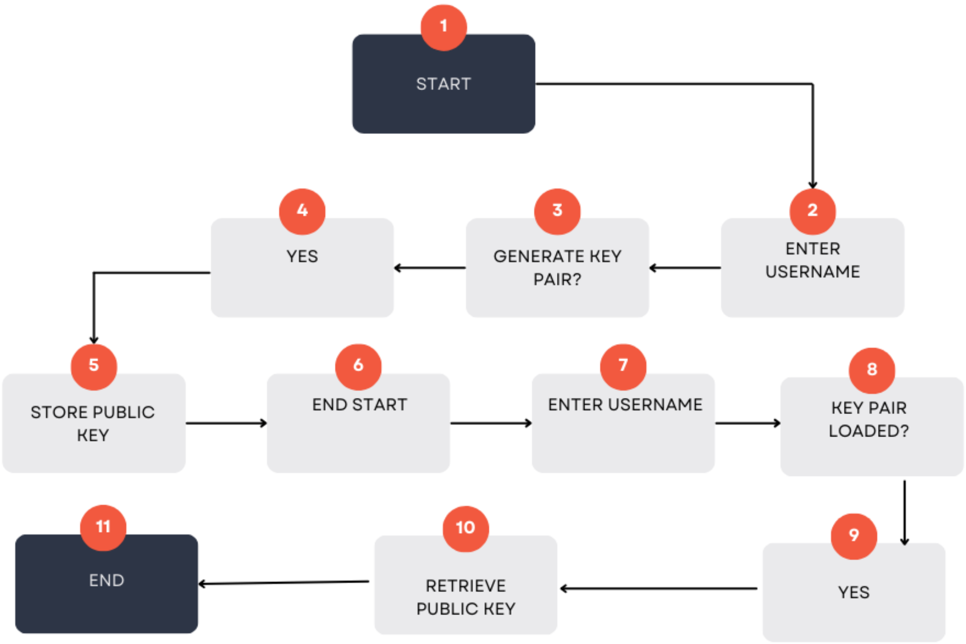
1. **Block** - A unit of data in the blockchain
2. **Hash** - Refers to the SHA256 hash used to secure each block in the blockchain
3. **Genesis Block** - The first block in the blockchain

List Of Figures and Diagrams:

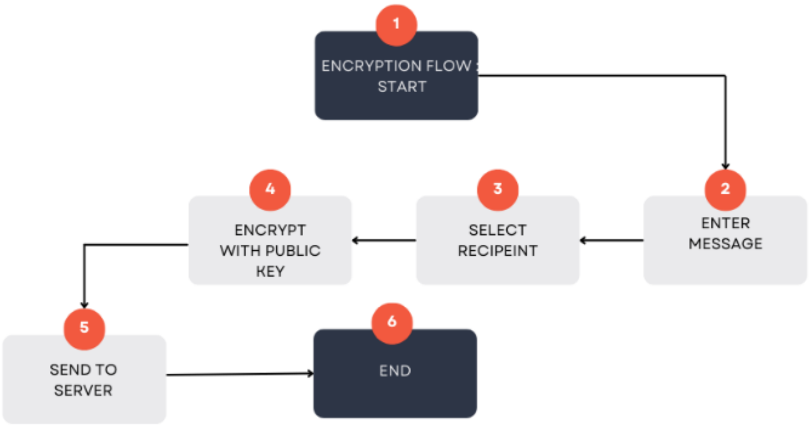
Message Flow:

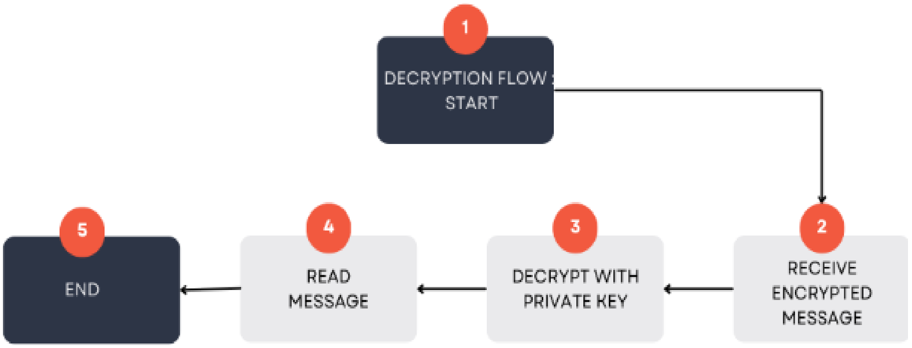


Client-Side Basic Interface:

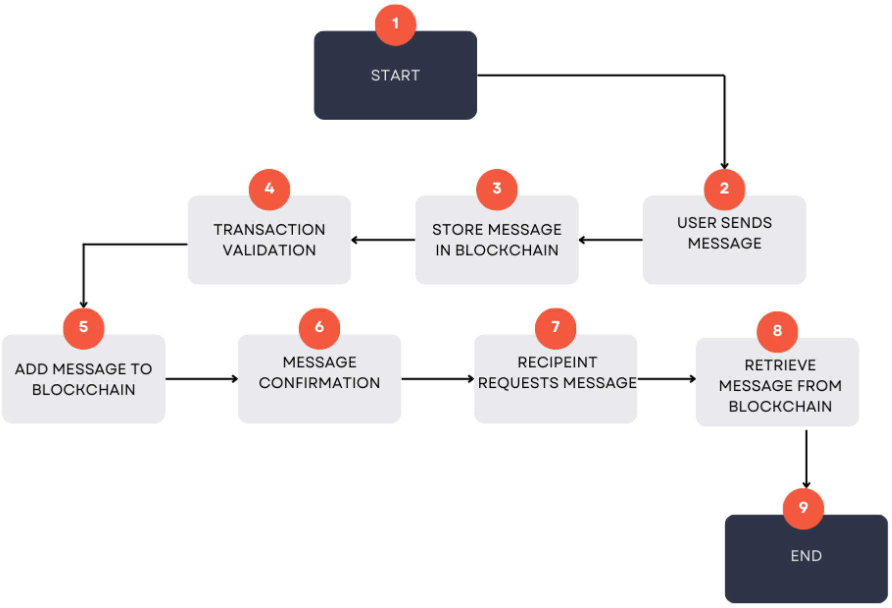


Encryption and Decryption flow:





Server-Side Flow



1
START
2
USER SENDS MESSAGE
3
STORE MESSAGE IN BLOCKCHAIN
4
TRANSACTION VALIDATION
5
ADD MESSAGE TO BLOCKCHAIN
6
MESSAGE CONFIRMATION
7
RECIPEINT REQUESTS MESSAGE
8
RETRIEVE MESSAGE FROM BLOCKCHAIN
9
END

Chapter 1: Project Description and Outline

In today’s digital environment, security and privacy have become important issues, especially when it comes to communication. The project aims to solve these issues by combining two powerful technologies to create a secure and private messaging platform: blockchain and RSA encryption. Transparency protects messages by ensuring they cannot be tampered with or deleted. Each message is encapsulated in a “block” that creates an encrypted, decentralized ledger of communications. This provides the sender and recipient with reliable and relevant information. Only the recipient with the private key can decrypt and read the message. By integrating RSA public key encryption technology, we prevent eavesdropping or unauthorized access by ensuring that messages are important and secure during transmission. The server-side application manages the blockchain, stores messages, and manages user records and queries, while the external application allows users to send and receive encrypted messages in real time using a peer. The ability to build a messaging platform with encryption that provides security, privacy, and integrity, which are important needs in today's world.

(1.1) Motivation Behind the Project:

In an age where digital communication is integrated into almost every aspect of our lives, the need for secure, private, and reliable messaging has never been greater. With concerns about data breaches, surveillance, and unauthorized access to personal data on the rise, the motivation behind the project is simple: give users full control over their communications, ensuring privacy, security, and trust in the digital world.

Traditional messaging systems often rely on centralized systems, leaving users vulnerable to attacks, privacy violations, and even censorship. Using blockchain technology, we can not only reduce the cost of communication, but also harness the power of cryptography to protect all messages from unauthorized access.

Our goal is to give people peace of mind knowing that their conversations are secure, immutable, and private, even in a world where threats are primarily cyber. This should be a priority, not an afterthought. As technology continues to evolve, we must protect digital communications.

By combining blockchain with RSA encryption, we are creating a platform that not only transforms messaging, but also sets new standards for privacy, integrity, and trust in the digital age. With every block added to the chain and every confidential message sent, we are contributing to a future where people can communicate easily and securely without fear of being monitored, intercepted, or stolen.

This vision inspired our decision to create a messaging system that can form the basis of secure digital communication in the future.

(1.2) Problem Statement:

In the modern digital landscape, messaging has become an essential part of both personal and professional communication. However, the vast majority of messaging platforms rely on centralized systems that are inherently vulnerable to a range of security threats. These include cyberattacks, data breaches, unauthorized surveillance, and the risk of tampering, all of which put sensitive user data at serious risk. As incidents of data exploitation, identity theft, and breaches of privacy continue to rise, trust in these centralized platforms has eroded.

In addition, many traditional messaging services offer little transparency regarding how data is handled, who can access it, and whether it can be manipulated. This lack of control over personal information, coupled with the potential for eavesdropping or interception, has left users questioning the privacy of their communications. As a result, individuals and organizations face an increasing challenge: how can they ensure that their messages are secure, private, and immune to external tampering or unauthorized access?

The pressing need is for a messaging system that provides not only confidentiality and data integrity but also user empowerment through full control over their communications. A solution that eliminates the risks of centralized infrastructures, resists cyber threats, and guarantees end-to-end security is crucial in ensuring the safety of digital communication in an increasingly connected world.

This project seeks to address these critical concerns by integrating blockchain technology with RSA encryption. By leveraging the decentralized, tamper-resistant properties of blockchain and the robust security of RSA encryption, we aim to create a secure messaging platform where users can trust that their communications are private, immutable, and fully under their control—no matter the digital threats they may face.

(1.3) Objective:

The project aims to create a secure, interactive network to ensure the privacy, integrity and confidentiality of digital communication. The project aims to solve fundamental problems such as data leakage, surveillance and unauthorized access to personal data in the normal language of the network by combining blockchain technology with RSA encryption.

According to blockchain security and transparency: Using blockchain technology to create a distributed, tamper-proof ledger to store information, ensuring that information cannot be changed, removed or tampered with once delivered to the supply chain. End-to-end encryption with RSA: Use RSA encryption to encrypt messages; allow only the intended recipient with the private key to decrypt and read messages. This ensures that communication remains confidential during transmission.

Communication is easy and reliable: Create a system with large and powerful capacity that ensures the security of sending messages even as the number of users and business grows over time.

Create a privacy-focused platform: Provide solutions that address user privacy by ensuring that no one can access or monitor communications without the user's permission. The project aims to set a new standard for secure digital communications by providing a platform where users can securely exchange messages without compromising known privacy or cyber threats.

Chapter 2: Related Work Investigation

(2.1) Literature Review:

Recently, blockchain technology has emerged as a potentially effective tool in the designof both secure and decentralized messaging systems. Ke Liang et al. (2024) introduce Eden, a blockchain interoperability protocol with a focus on clearly provable security and exceptional speed, setting a foundation for integrating decentralized messaging platforms across different blockchains [1]. Mirza K. B. Shuhan et al. (2023) propose Quarks, a secure, blockchain-based messaging network that focuses on end-to-end encryption and message integrity, directly aligning with our goal of ensuring secure communication in decentralized systems [2]. Zhang and Pan (2022) investigate secure communication models for instant messaging, evaluating cryptographic protocols like RSA encryption to ensure data confidentiality and authenticity, essential components in our platform's cryptographic foundation [3]. The paper on secure peer-to-peer communication using private blockchain technology (2023) highlights blockchain's tamper-proof nature, which aligns with our emphasis on decentralization and protecting message data from unauthorized access [4]. Chirag Jania et al. (2020) present a blockchainized decentralized messaging application tailored for educational institutes, showcasing the integration of blockchain and RSA encryption to secure communication and maintain message integrity, closely related to our approach [5]. Venkat Jayaram Vikram et al., 2021, investigated the use of blockchain in messaging applications, underlining the validation and timestamping of messages to maintain the integrity of messages, one of the most critical features of our platform [6]. Yang Liu et al., 2020, checked the application of blockchain-based identity management systems that ensure secure user authentication, another crucial factor for implementing messaging platform decentralization [7]. Additionally, S. Rouhani and R. Deters (2019) examines the aspects of security and efficiency pertaining to smart contracts, which play a crucial role in the automation and safeguarding of communication processes within a blockchain-oriented framework [8]. U.P. Eillewala et al. (2022) and Prashant Madhav Sonawane et al. (2021) explore messaging platforms that leverage blockchain technology, highlighting the importance of message immutability and consensus mechanisms in blockchain to uphold data confidentiality and message integrity in decentralized applications [9][10]. Chibuzor

Udokwu and colleagues (2022) assess multiple methodologies for the design of decentralized applications, with a particular focus on messaging systems, emphasizing the critical roles of security and scalability in the creation of resilient blockchain-based platforms [11]. Goel and associates (2022) investigate the amalgamation of Web 3.0 technologies with decentralized applications to facilitate secure communication and data storage, which is pertinent to our research on the implementation of decentralized secure messaging systems [12]. Günther et al. (2021) examine the application of blockchain technology in safeguarding privacy within digital communications, highlighting the role of public-key cryptography in bolstering security by establishing a confidential communication channel for users operating in decentralized settings [13]. Gupta et al. (2022) concentrate on the effective incorporation of blockchain into messaging protocols, introducing a framework that guarantees rapid transmission and substantial throughput while upholding both security and privacy [14]. Liang et al. (2021) conduct an examination of blockchain-based frameworks for encrypted communication, emphasizing the manner in which decentralized applications utilize public-key cryptography to establish secure channels [15]. Karami et al. (2021) propose an innovative strategy for encrypted messaging on the blockchain that ensures the implementation of zero-knowledge proofs to uphold confidentiality [16]. Wang et al. (2022) investigate the utilization of blockchain technology and cryptographic hash functions to enhance the security of messaging services and generate immutable logs, which corresponds with our aim of maintaining data integrity and audibility in communications [17]. Dinh et al. (2020) introduce a decentralized messaging architecture that leverages blockchain to eliminate server-side governance, thereby rendering communication resistant to censorship [18]. Chang et al. (2021) discuss the potential for decentralized identity management in blockchain messaging systems, ensuring user privacy against centralized vulnerabilities [19]. Hwang et al. (2022) also investigate the perspective concerning smart contract application for the purpose of enhancing the security level of the messaging protocol and enabling automated verification of the message in blockchain networks [20]. Kumar et al. (2023) focus on the security aspects of messaging networks based on blockchain infrastructure and their integration with cryptographic schemes for ensuring data integrity and privacy [21]. Liu et al. (2022) proposed a new consensus mechanism to improve scalability and security in decentralized messaging platforms for more efficient processing of messages with consistency in data [22]. Chen et al. (2023) examine the application of blockchain technology and cryptographic methods to develop secure messaging systems within the framework of Internet of Things (IoT) networks, illustrating how blockchain can improve security within decentralized contexts [23].

(2.2) Conclusion:

Existing literature highlights the great potential of blockchain technology for enhancing security, privacy, and decentralization among messaging systems. By marriage of blockchain to RSA encryption, we've put together a messaging platform that guarantees the privacy of data, the integrity of messages, and secure user authentication. Our implementation leverages the immutability characteristics of blockchain, cryptographic encryption methodologies, and smart contracts to establish an immensely secure and decentralized messaging framework, assuring total confidentiality and safeguard to these messages in a continually digital environment.

Chapter 3: Requirements Artifacts

The requirements artifacts for the decentralized messaging application based on the given code are mainly focused on system security, data integrity, and decentralization. They include the Business Requirements Document (BRD), Functional Requirements Specification (FRS), and Non-Functional Requirements (NFRs), all of which articulate critical expectations and goals that are aligned with the system's design and implementation in the project.

(3.1) Business Requirements Document (BRD)

The BRD emphasizes the need for secure, private communication using a decentralized architecture. The system must allow users to register, exchange encrypted messages, and retrieve them via a blockchain-based approach. The business goal is to ensure that no central authority controls the data, offering an immutable, censorship-resistant messaging platform. The project also aims to deliver privacy in an enhanced form via end-to-end encryption that utilizes RSA key pairs and ensures that only the desired recipient can read the message.

(3.2) Functional Requirements Specification (FRS)

The FRS indicates the core functional aspects of the system. They encompass user registration through generation of public/private keys, stored in a decentralized ledger. The system will then permit sending and retrieving of encrypted messages and manage blockchain data integrity. The system should also enable users to send encrypted messages to different recipients based on their respective public keys and store messages on the blockchain in a way that once recorded cannot be modified or deleted. In addition, users ought to be able to receive their messages from the blockchain by decrypting them through their private keys. The system handles messages through socket communication, with client-side encryption and server-side blockchain management.

(3.3) Non-Functional Requirements (NFRs)

The NFRs focus on ensuring the application’s efficiency, scalability, and security. The system should be able to handle a growing number of users and messages without performance degradation. Latency in message sending and retrieval should be minimal to ensure real-time communication. The blockchain should guarantee fault tolerance, meaning loss of data is impossible unless all nodes are unavailable at the same time. More importantly, the application shall adhere to security best practices, such as proper management of keys, encrypted messages storage, and strong defences against unauthorized access.

These requirements artifacts provide a structured way of developing the decentralized messaging application, ensuring that such a system meets both users' expectations for privacy and security and technical standards on performance and scalability.

Chapter 4: Design Methodology and Its Novelty

The design methodology for the decentralized messaging application focuses on providing a highly secure, private, and censorship-resistant communication platform through a combination of blockchain technology and RSA encryption. The core design methodology is based on modular architecture, where different components—client-side, server-side, and blockchain interaction—are developed to work seamlessly together to ensure robust security, scalability, and decentralization.

- **Modular Architecture:** The application is developed following a layered design in which each module performs some tasks. The client application mainly focuses on user authentication, encryption, and communication. The server application focuses on blockchain management, in which it stores encrypted messages, processes, and manages user requests. This modular architecture separates different parts of the system that can be scaled independently without affecting the other. In this case, the blockchain is used as a back-end service that can protect messages, creating an immutable and decentralized ledger.
- An essential part of the design includes the integration of blockchain technology to manage the storage of messages. In contrast to traditional systems where messages are stored in a centralized server, this approach uses a custom blockchain to store all messages in a decentralized and tamper-proof ledger. Since every message is stored as a block, once written, the messages cannot be deleted or changed, thus assuring the highest level of data integrity. The blockchain is used both as a message storage solution and to validate transactions between the client and the server to ensure that all transactions are secure.
- RSA-based End-to-End Encryption: In this application, RSA is used for encryption purposes. It generates the public and private keys on the local machine of the client side. Public keys are utilized for encryption when a user sends a message, and private keys are used to decrypt that message. In this process, end-to-end encryption is done in such a way that if the blockchain or server gets compromised, the messages remain safe and unreadable for the unwanted users.

- The blockchain design is scalable, in the sense that it will accommodate growth as more people come into the network. Decentralization also guarantees that the system is fault-tolerant, which implies that even if a node fails or becomes unreachable, the entire system continues to operate in an error-free manner.

(4.1) Novelty of Design

This design novelty is in the integration of blockchain for message storage with end-to-end encryption using RSA. Although blockchain has been used widely in cryptocurrencies and other decentralized applications, its use for secure and immutable message storage is relatively new. The system does not require a central authority and thus reduces the risk of censorship and ensures complete privacy for users.

In addition, since RSA is utilized for encryption, and this is coupled with the characteristic of blockchain as immutable, it makes it extremely tough for an attacker to intercept, modify, or delete messages. This is even more advanced than traditional systems that use encryption-based messaging systems by centralized servers, providing an extremely more robust solution for tampering and unauthorized access.

In essence, the combination of RSA encryption and blockchain technology in this messaging system brings a novel approach to secure, decentralized communication, ensuring that privacy, data integrity, and security are at the core of the user experience.

Chapter 5: Technical Implementation and Analysis

(5.1) Overview:

The decentralized messaging application allows secure communication between users via encrypted messages stored on a custom blockchain. The architecture is based on client-server interactions, with the client responsible for encryption, and the server handling message storage on the blockchain.

(5.2) Key Components:

I. Client-Side Application:

- Generates and stores RSA key pairs for encryption.
- Provides a user interface for sending and retrieving encrypted messages.
- Communicates directly with the server using socket connections.

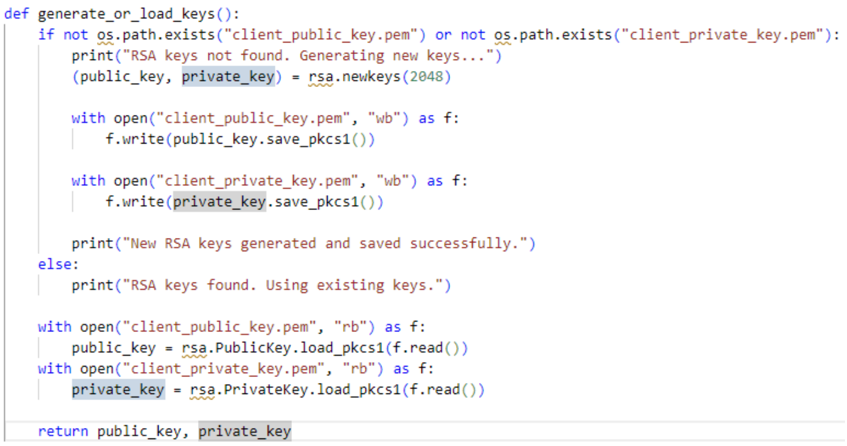
II. Server-Side Application:

- Manages the blockchain for storing messages securely.
- Provides endpoints for sending and retrieving messages.
- Uses RSA encryption for message security.

(5.3) Detailed Code Implementation:

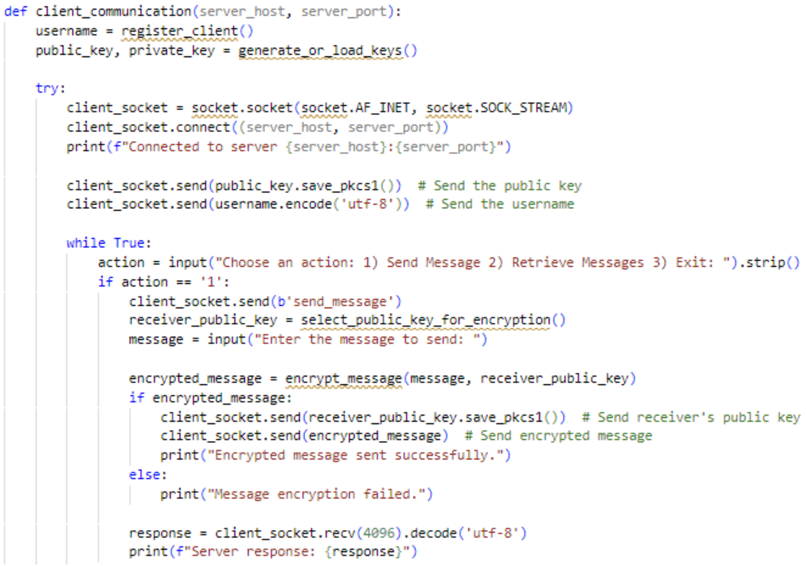
The client-side generates RSA keys, encrypts messages, and sends them to the server. It also retrieves encrypted messages, decrypts them, and displays them to the user.

I. Client-Side (Key Generation & Message Encryption):



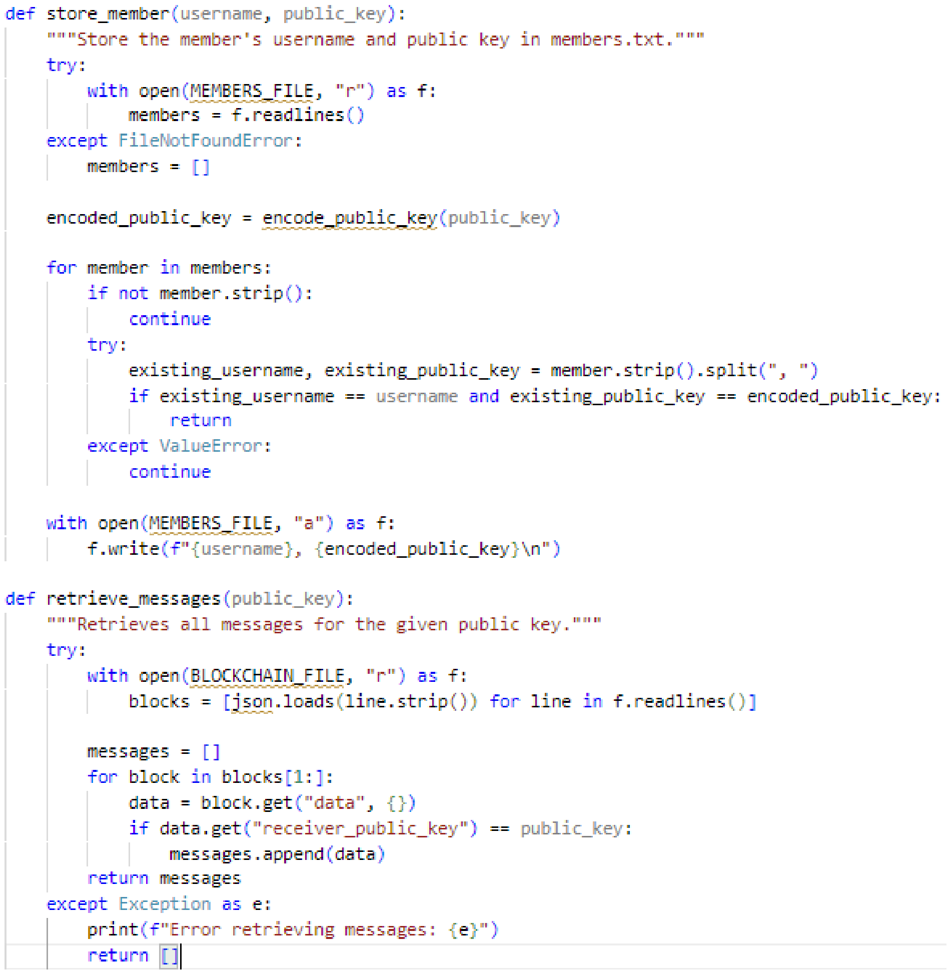
```
def generate_or_load_keys():
    if not os.path.exists("client_public_key.pem") or not os.path.exists("client_private_key.pem"):
        print("RSA keys not found. Generating new keys...")
        (public_key, private_key) = rsa.newkeys(2048)

        with open("client_public_key.pem", "wb") as f:
            f.write(public_key.save_pkcs1())

        with open("client_private_key.pem", "wb") as f:
            f.write(private_key.save_pkcs1())

        print("New RSA keys generated and saved successfully.")
    else:
        print("RSA keys found. Using existing keys.")

    with open("client_public_key.pem", "rb") as f:
        public_key = rsa.PublicKey.load_pkcs1(f.read())
    with open("client_private_key.pem", "rb") as f:
        private_key = rsa.PrivateKey.load_pkcs1(f.read())

    return public_key, private_key
```

II. Client-Side Communication:



```
def client_communication(server_host, server_port):
    username = register_client()
    public_key, private_key = generate_or_load_keys()

    try:
        client_socket = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        client_socket.connect((server_host, server_port))
        print(f"Connected to server {server_host}:{server_port}")

        client_socket.send(public_key.save_pkcs1())  # Send the public key
        client_socket.send(username.encode('utf-8'))  # Send the username

        while True:
            action = input("Choose an action: 1) Send Message 2) Retrieve Messages 3) Exit: ").strip()
            if action == '1':
                client_socket.send(b'send_message')
                receiver_public_key = select_public_key_for_encryption()
                message = input("Enter the message to send: ")

                encrypted_message = encrypt_message(message, receiver_public_key)
                if encrypted_message:
                    client_socket.send(receiver_public_key.save_pkcs1())  # Send receiver's public key
                    client_socket.send(encrypted_message)  # Send encrypted message
                    print("Encrypted message sent successfully.")
                else:
                    print("Message encryption failed.")

                response = client_socket.recv(4096).decode('utf-8')
                print(f"Server response: {response}")
```

III. Server-Side (Blockchain Management & Message Handling):



```
def store_member(username, public_key):
    """Store the member's username and public key in members.txt."""
    try:
        with open(MEMBERS_FILE, "r") as f:
            members = f.readlines()
    except FileNotFoundError:
        members = []

    encoded_public_key = encode_public_key(public_key)

    for member in members:
        if not member.strip():
            continue
        try:
            existing_username, existing_public_key = member.strip().split(", ")
            if existing_username == username and existing_public_key == encoded_public_key:
                return
        except ValueError:
            continue

    with open(MEMBERS_FILE, "a") as f:
        f.write(f"{username}, {encoded_public_key}\n")

def retrieve_messages(public_key):
    """Retrieves all messages for the given public key."""
    try:
        with open(BLOCKCHAIN_FILE, "r") as f:
            blocks = [json.loads(line.strip()) for line in f.readlines()]

        messages = []
        for block in blocks[1:]:
            data = block.get("data", {})
            if data.get("receiver_public_key") == public_key:
                messages.append(data)
        return messages
    except Exception as e:
        print(f"Error retrieving messages: {e}")
        return []
```

(5.4) Analysis:

I. **Security and Privacy**:

- RSA encryption ensures that only the intended recipient can decrypt the message.
- Blockchain guarantees immutability, preventing tampering with stored messages.

II. **Scalability**:

- Blockchain's linear structure can become inefficient as more messages are added. For large-scale systems, integrating decentralized storage (like IPFS) for message data could reduce blockchain bloat.

III. **Fault Tolerance**:

- The use of FileLock ensures that blockchain file writes are safe from concurrent access, providing robustness.

IV. **Usability**:

- The client provides a simple interface for users to send and retrieve encrypted messages without understanding the underlying encryption mechanisms.

V. **Performance**:

- Message retrieval is linear in time complexity due to the need to scan the entire blockchain. Optimizations, such as indexing, could improve performance for large datasets.

Chapter 6: Program Outcomes and Its Applicability

(6.1) Program Outcomes:

1. **Secure Communication**:
   The application ensures end-to-end encrypted messaging using RSA, guaranteeing the confidentiality of messages even in decentralized environments.
2. **Decentralized Storage**:
   Messages are stored immutably on a custom blockchain, eliminating central points of failure and ensuring data integrity.
3. **User Privacy**:
   User identities are managed via public/private key pairs, preserving anonymity and preventing unauthorized access.
4. **Censorship Resistance**:
   The decentralized architecture ensures that no single entity can censor or manipulate the messaging system.
5. **Scalability**:
   By leveraging blockchain and P2P communication principles, the system can scale horizontally, accommodating more users and messages.
6. **User-Friendly Client Interface**:
   The client-side application simplifies user interaction by automating key generation, encryption, and blockchain interactions.

(6**.2) Applicability:**

This decentralized messaging application has broad applicability across various domains where secure and private communication is essential. For personal use, it offers individuals a platform to communicate confidentially without concerns about data breaches or censorship. In the corporate world, organizations can leverage the system to establish secure communication channels, ensuring sensitive business information remains protected from unauthorized access. Activists and journalists working in regions with restricted freedom of speech can benefit from its censorship-resistant architecture to share information safely and anonymously. Additionally, the platform can serve industries like healthcare and finance, where the secure exchange of sensitive data, such as patient records or financial transactions, is critical. Moreover, as an educational and research tool, it provides an excellent example of combining cryptographic techniques and blockchain technology to create decentralized systems. Developers can also use this application as a foundational prototype to build other decentralized applications, such as voting systems or supply chain solutions, showcasing its versatility and adaptability.

Chapter 7: Conclusion and Recommendation

(7.1) Conclusion:

The decentralized messaging application demonstrates a secure, private, and tamper-proof communication platform by integrating RSA encryption and a custom blockchain infrastructure. This innovative approach ensures that messages remain confidential and immutable, addressing critical concerns of data security and privacy. The application's ability to function without reliance on centralized servers enhances its resilience against censorship and unauthorized data access, making it particularly valuable for users in high-risk or sensitive environments. By focusing on a user-friendly client-side experience and leveraging blockchain technology for secure message storage, the project establishes a robust foundation for decentralized communication.

(7.2) Recommendation:

To maximize the effectiveness and scalability of the application, the following recommendations are proposed:

1. **Enhanced User Key Management**: Introduce secure backup and recovery mechanisms for RSA private keys to prevent loss of access to messages due to misplaced or corrupted keys.
2. **Scalability Optimization**: Implement advanced blockchain optimization techniques, such as sharding or off-chain storage for older messages, to manage increased user and message volumes.
3. **Integration with Decentralized Storage Systems**: Consider integrating decentralized storage solutions like IPFS for larger message or multimedia attachments, ensuring scalability and efficiency.
4. **Improved Usability**: Develop a more intuitive graphical user interface (GUI) for the client-side application to increase adoption among non-technical users.
5. **Advanced Security Features**: Add support for two-factor authentication or biometric security to provide an additional layer of protection for user accounts.

6. **Continuous Testing and Updates**: Regularly test the application for vulnerabilities and provide updates to maintain its security and functionality in an evolving threat landscape.
7. **Community Engagement**: Build an active user community to provide feedback, drive adoption, and contribute to the continuous improvement of the platform.

By addressing these recommendations, the application can evolve into a highly efficient, user-friendly, and secure decentralized communication tool with diverse applicability.

References

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