Report – Secure Chat App with End-to-End Encryption

1. Introduction

The increasing reliance on digital communication has made security and privacy paramount. With the proliferation of messaging platforms, users expect confidentiality, integrity, and authenticity in their conversations. However, many popular solutions either lack true end-to-end encryption or implement it poorly, exposing users to the risk of eavesdropping and data breaches. This project addresses these concerns by developing a Secure Chat Application that leverages robust cryptographic techniques to guarantee that only intended participants can access message content, regardless of server compromise or network interception.

2. Abstract

The Secure Chat App is designed as a real-time messaging platform with a strong focus on user privacy and data security. It implements a hybrid encryption system, combining RSA (asymmetric) for secure key exchange and AES (symmetric) for fast, efficient message encryption. The application ensures that all chat messages and logs are encrypted both in transit and at rest, making it impossible for unauthorized parties — including the server administrators — to access sensitive user data. The system architecture also supports group chats, secure key management, and a responsive web interface, making it a practical demonstration of modern secure messaging principles.

3. Tools Used

- Python 3: The primary programming language for server-side and cryptographic logic.
- Flask: A lightweight web framework used to build the server-side application and RESTful APIs.
- Flask-SocketIO: Enables real-time, bi-directional communication between clients and the server, crucial for instant messaging.
- Cryptography Library: Implements RSA for public/private key management and AES for encrypting/decrypting chat messages.
- HTML, CSS, JavaScript: Used for building the interactive and user-friendly frontend.
- Eventlet: Provides asynchronous support for Flask-SocketIO, ensuring scalable real-time communication.
- Other Utilities: Libraries such as `os` and `json` for file handling and data serialization.

4. Steps Involved in Building the Project

4.1. Project Planning and Architecture Design:

- Defined requirements for end-to-end encryption, user registration, secure key management, real-time messaging, and encrypted log storage.
- Designed a modular architecture with clear separation between backend logic, encryption routines, and frontend assets.

4.2. Backend Implementation:

- Flask App Structure – Created an organized `app/` directory containing modules for initialization, main server logic, models, encryption utilities, and chat log handling.
- User Registration and Authentication – Implemented secure user registration, generating an RSA key pair for each user. Public keys are exchanged and stored for encrypted communication.
- Key Exchange Mechanism – Used RSA to securely exchange AES session keys between users, ensuring only intended recipients can decrypt messages.

4.3. End-to-End Message Encryption:

- AES Encryption – All chat messages are encrypted with a unique AES key before transmission.
- RSA Key Exchange – AES keys are exchanged using recipients' RSA public keys, ensuring that only the intended user can decrypt the AES key and thus the message.

4.4. Encrypted Chat Logs:

- All chat logs are encrypted with AES before being saved on the server. This ensures that even if server files are compromised, message content remains protected.

4.5. Frontend Development:

- Developed an intuitive interface using HTML, CSS, and JavaScript within the `static/` directory, allowing users to register, log in, and participate in secure chats.
- Implemented real-time chat functionality with Socket.IO, enabling seamless message delivery and updates.

4.6. Testing and Security Verification:

- Performed extensive testing for message delivery, encryption/decryption correctness, and group chat key management.
- Verified that no plaintext messages or keys were stored or transmitted, and that all cryptographic routines followed best practices.

4.7. Documentation and Deployment:

- Prepared detailed setup instructions and usage guidelines in `README.md`.
- Documented security decisions, limitations, and recommendations for further improvement.

5. Conclusion

The Secure Chat App with End-to-End Encryption demonstrates the practical application of strong cryptographic principles in a modern web messaging platform. By leveraging hybrid encryption (RSA + AES), the system ensures that only intended recipients can access message content, even if the server is compromised. The architecture effectively addresses common security threats such as eavesdropping, data leakage, and unauthorized access. Moreover, the use of encrypted logs and real-time communication technologies showcases a comprehensive approach to privacy and usability. This project serves as a robust foundation for further exploration into secure group messaging, forward secrecy, and advanced authentication mechanisms, contributing meaningfully to the field of secure digital communications.

6. References

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