Secure Chat Application – Project Report

1. Project Overview

This project implements a **secure, multi-client chat application** using Python. It provides **end-to-end encryption**, **user authentication**, and supports **sending text messages and files**.

The system is based on a **client-server architecture**, with:

- A **graphical interface** for clients (using `customtkinter`)
- A **console-based interface** for the server

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2. Key Features

✅ Secure Communication

- **Key Exchange**: Uses **X25519** elliptic curve Diffie-Hellman protocol for secure key exchange.
- **Authenticated Encryption**: Messages and files are encrypted using **AES-256-GCM**.
- **Key Derivation**: Employs **HKDF** (HMAC-based Key Derivation Function) for AES key generation.

👥 Multi-Client Support (Server)

- Server handles multiple clients concurrently using **threading**, allowing real-time communication with several users.

📁 File Transfer

- Supports **encrypted file sharing**.
- Files are distinguished using a `b'FILE'` **prefix** and saved after decryption on the server.

🔐 User Authentication

- Users must **login with a username and password** before chatting.
- Server validates credentials (currently hardcoded for demo purposes).

💬 Interactive GUI (Client)

- Built using **customtkinter**.
- Features:
    - **Dark/Light themes**
    - **Emoji support**
    - **Typing indicators** (like WhatsApp)
    - **Message alignment** (sent from right, received from left)

📡 Robust Data Transfer

- Uses **length-prefixing** to ensure accurate message/file transmission.
- Prevents message truncation or partial reads over the socket.

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3. Architecture

📌 Server (`server.py`)

- Listens for incoming connections
- Performs:
    - Secure key exchange
    - User authentication
    - Message decryption & broadcast
    - File saving (with decryption)

- Creates a thread per client for real-time handling

📌 Client (`client.py`)

- Connects to server, performs key exchange & authentication
- Provides a GUI chat interface with:
    - Real-time messaging
    - File upload
    - Emoji picker
    - Typing indicator
    - Theme toggle

📌 Crypto Utilities (`crypto_utils.py`)

- Manages:
    - Key generation
    - Shared secret derivation
    - AES encryption/decryption
    - Public key serialization/deserialization

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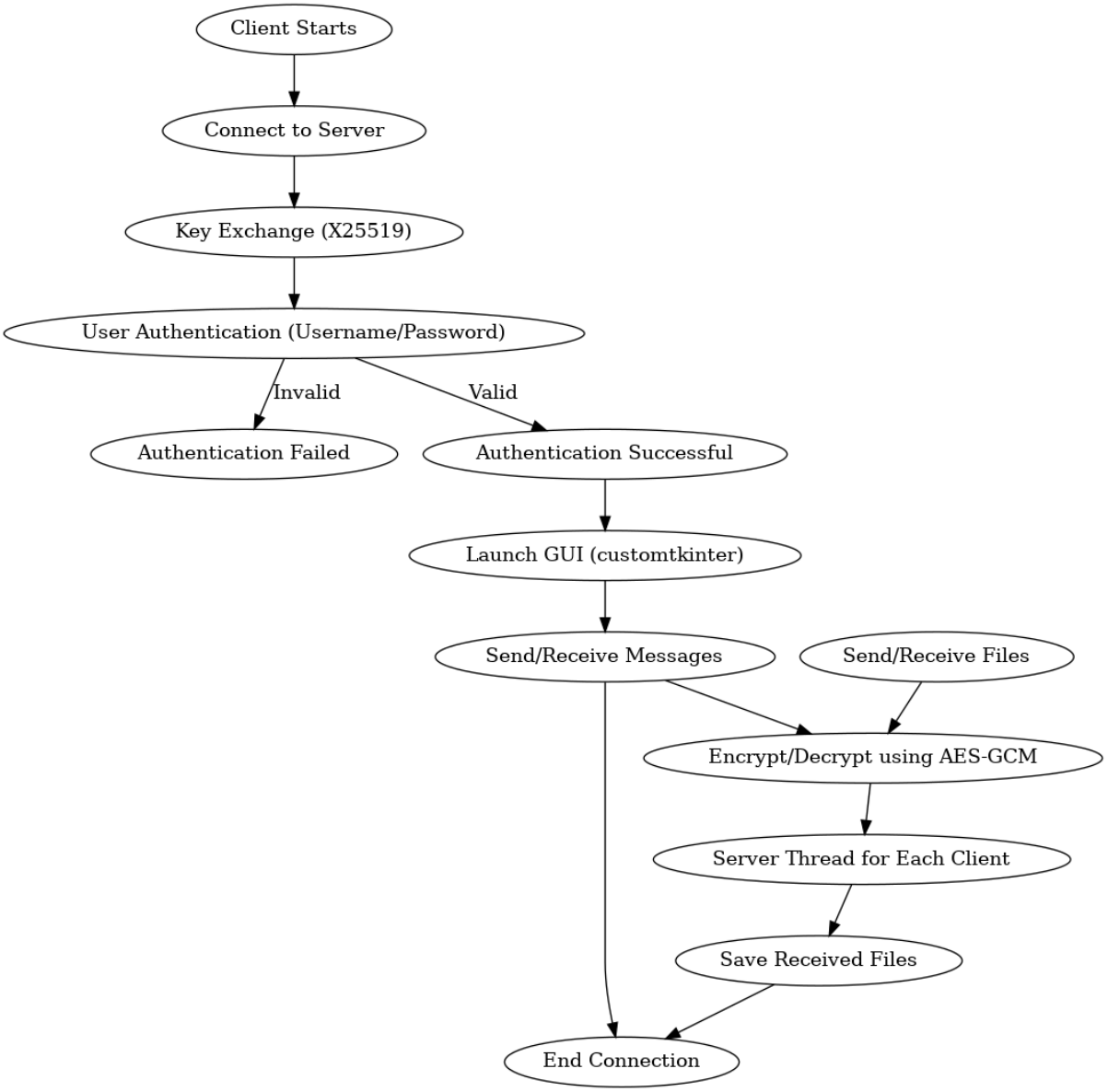
4. Flowchart



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5. Methodology

🔧 Foundational Setup

- Established TCP connection using `socket` module
- Built multi-threaded server for concurrency

🔐 Cryptographic Core

- Implemented **crypto_utils.py**
- Integrated **X25519**, **AES-GCM**, and **HKDF**

🧱 Reliable Data Transfer

- Added **4-byte length-prefixing** using `struct`
- Ensured complete message reads

🎨 GUI Development

- Used `customtkinter` to create modern GUI
- Added:
    - Message panels
    - Emoji picker
    - Typing status display
    - Theme toggle

🔐 Authentication Layer

- Added login screen to client
- Server checks credentials before allowing chat

📁 File Transfer Implementation

- Enabled encrypted file sharing from client to server
- Used `filedialog` for file selection
- Server saves files post-decryption

🧪 Testing & Refinement

- Stress-tested encryption, communication, and file transfer

- Handled edge cases (incomplete reads, disconnects)
- Improved feedback and error messages

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6. Technical Details

Category	Technology Used
Programming Language	Python 3.x
Networking	`socket` module (TCP/IP)
Concurrency	`threading` module
Cryptography	`cryptography` package
GUI Framework	`customtkinter`
Data Structuring	`struct` module (for message framing)
File Handling	`os`, `filedialog` from `tkinter`

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7. Conclusion

This project demonstrates how **cryptography**, **networking**, and **GUI design** can be combined to build a **real-time secure communication system**. It provides a complete client-server model with a **focus on security, usability, and scalability**. Future improvements may include:

- Encrypted message storage
- Group chat support
- Voice/video calling
- Database-backed user authentication
