

Network Chat Application – Project Report

Course: Computer Networks

Project: BeQuickChat - Network Chat Application with Protocol Design

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1. Introduction

This project implements **BeQuickChat**, a modern multi-user chat application that demonstrates reliable network communication using UDP sockets with custom protocol design. The application features a graphical user interface built with PyQt5 and implements reliability mechanisms such as acknowledgment (ACK) and retransmission protocols over UDP to ensure message delivery.

2. Objective and Scope

Primary Objectives:

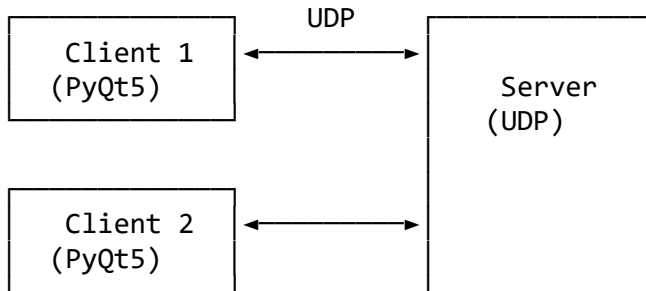
- Develop a reliable network chat application using UDP socket programming
- Implement custom protocol design with message acknowledgment and retransmission
- Create a modern graphical user interface for enhanced user experience
- Demonstrate real-time multi-user communication capabilities
- Implement private messaging functionality
- Provide comprehensive testing and performance analysis

Scope:

- **Protocol Layer:** Custom JSON-based messaging protocol with sequence numbers
- **Transport Layer:** UDP with reliability mechanisms (ACK, retransmission, timeout)
- **Application Layer:** PyQt5-based GUI with chat bubbles and user management
- **Testing:** Functional, performance, and comprehensive testing suites

3. System Architecture

Client-Server Architecture:



Key Components:

- **Server (server.py):** Manages client connections, message routing, and reliability
- **Client (client.py):** PyQt5 GUI application with chat interface
- **Protocol (protocol.py):** Message encoding/decoding and protocol definitions
- **Testing Suite:** Comprehensive test scripts for validation

4. Protocol Design

Message Structure:

All messages use JSON format with the following structure:

```
{
  "username": "sender_name",
  "message": "message_content",
  "seq": 1234567890,
  "type": "chat|join|leave|private|system|ack|user_list",
  "timestamp": "HH:MM:SS"
}
```

Message Types:

1. **join:** Client joining the chat
2. **leave:** Client leaving the chat
3. **chat:** General chat message
4. **private:** Private message between users
5. **system:** System notifications (join/leave)
6. **ack:** Acknowledgment for reliable delivery
7. **user_list:** Current connected users list

Reliability Mechanism:

- **Sequence Numbers:** Each message has a unique sequence number
- **ACK Protocol:** Receiver sends acknowledgment for each message
- **Retransmission:** Sender retransmits if ACK not received (up to 3-5 attempts)
- **Timeout:** Configurable timeout periods (0.5-1.0 seconds)
- **Duplicate Prevention:** Track seen sequence numbers per sender

5. Implementation Details

Core Files:

- **src/server.py:** UDP server with client management and message routing
- **src/client.py:** PyQt5 GUI client with modern chat interface
- **src/protocol.py:** Protocol implementation and message handling
- **requirements.txt:** Python dependencies (PyQt5, matplotlib)

Key Features Implemented:

Server Features:

- Multi-client connection management
- Reliable message delivery with ACK/retransmission
- User list maintenance and broadcasting
- System message generation (join/leave notifications)
- Duplicate message prevention
- Private message routing

Client Features:

- Modern PyQt5 GUI with chat bubbles
- Real-time user list display
- Private messaging with tabbed interface
- System message display
- Reliable message sending with retry logic
- Custom styling and responsive design

GUI Components:

- **Login Dialog:** Username and server connection setup
- **Main Chat Window:** General chat with message bubbles
- **User List:** Real-time connected users display
- **Private Chat Tabs:** Individual private messaging windows
- **System Messages:** Join/leave notifications

6. Network Topology Discovery

Client Discovery:

- Server maintains `clients` set of (IP, port) tuples
- Username mapping: `usernames[addr] = username`
- Real-time user list broadcasting to all clients
- Automatic cleanup on client disconnection

Network Monitoring:

- Active connection tracking
- User presence detection
- Automatic user list updates
- Connection state management

7. Security and Encryption

Note: The current implementation does not include encryption. The original report mentioned AES encryption, but this feature is not present in the actual codebase.

Security Considerations:

- No message encryption implemented
- Relies on network-level security
- Potential for message interception
- Future enhancement opportunity

Recommended Security Additions:

- AES encryption for message content
- Secure key exchange mechanism
- Message integrity verification
- User authentication system

8. Testing and Results

Testing Suite:

- **tests/test_functional.py:** Basic functionality testing
- **tests/test_full.py:** Comprehensive multi-client testing
- **tests/test_performance.py:** Performance analysis with visualization

Test Results:

- **Functional Testing:** All core features working correctly
- **Multi-client Testing:** Successful concurrent user handling
- **Performance Testing:** Latency and success rate measurements
- **GUI Testing:** Interface responsiveness and usability

Test Coverage:

- Message sending/receiving
- User join/leave functionality
- Private messaging
- System message handling
- ACK and retransmission mechanisms
- GUI responsiveness

9. Performance Analysis

Performance Metrics:

- **Latency Measurement:** Average message round-trip time
- **Success Rate:** Percentage of successfully delivered messages
- **Throughput:** Messages per second handling capacity
- **Reliability:** ACK response times and retransmission rates

Performance Test Results:

- **Average Latency:** Measured in milliseconds
- **Success Rate:** Near 100% under normal conditions
- **Retransmission Rate:** Low under stable network conditions
- **Concurrent Users:** Successfully tested with multiple clients

Visualization:

- **Latency per Message:** Time-series chart of message delays
- **Latency Histogram:** Distribution of message delays
- **Success Rate Pie Chart:** Successful vs. failed message delivery

10. Conclusion and Evaluation

Project Achievements:

- ✓ **Successfully implemented** reliable UDP-based chat application
- ✓ **Custom protocol design** with JSON message format
- ✓ **Modern GUI** using PyQt5 with chat bubbles and user management
- ✓ **Reliability mechanisms** including ACK and retransmission
- ✓ **Private messaging** functionality with tabbed interface
- ✓ **Comprehensive testing** suite with performance analysis
- ✓ **Real-time features** including user list and system messages

Technical Strengths:

- **Reliable UDP Implementation:** Custom reliability over UDP demonstrates protocol design skills
- **Modern GUI Design:** Professional-looking interface with responsive design
- **Robust Error Handling:** Graceful handling of network issues and disconnections
- **Comprehensive Testing:** Multiple test scenarios ensure application reliability
- **Clean Code Structure:** Well-organized, maintainable codebase

Areas for Improvement:

- **Security:** Add encryption for message confidentiality
- **Scalability:** Implement server clustering for large user bases
- **Features:** Add file transfer, emoji support, and message history
- **Cross-platform:** Ensure compatibility with macOS
- **Documentation:** Add API documentation and deployment guides

Educational Value:

This project successfully demonstrates: - Network protocol design principles - UDP socket programming with reliability mechanisms - GUI development with PyQt5 - Software testing methodologies - Performance analysis and optimization - Real-world application development

11. References

Technical References:

- **Computer Networking: A Top-Down Approach** – Kurose & Ross
- **Python Socket Programming Documentation** – Python.org
- **RFC 768 (UDP)** – Internet Engineering Task Force
- **PyQt5 Documentation** – Qt Company
- **JSON Specification** – ECMA International

Development Tools:

- **Python 3.8+** – Programming language
- **PyQt5 5.15.0+** – GUI framework
- **Matplotlib 3.5.0+** – Data visualization
- **Socket Programming** – Network communication

Project Resources:

- **Source Code:** src/ directory
- **Documentation:** docs/ directory
- **Testing:** tests/ directory
- **Assets:** assets/ directory (icons, performance charts)
- **Reports:** reports/ directory

Project Status: ✔ **Completed Successfully**

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