Building a Scalable Chat Server with WebSocket and SQLite

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Introduction

Bob Liu Boyu

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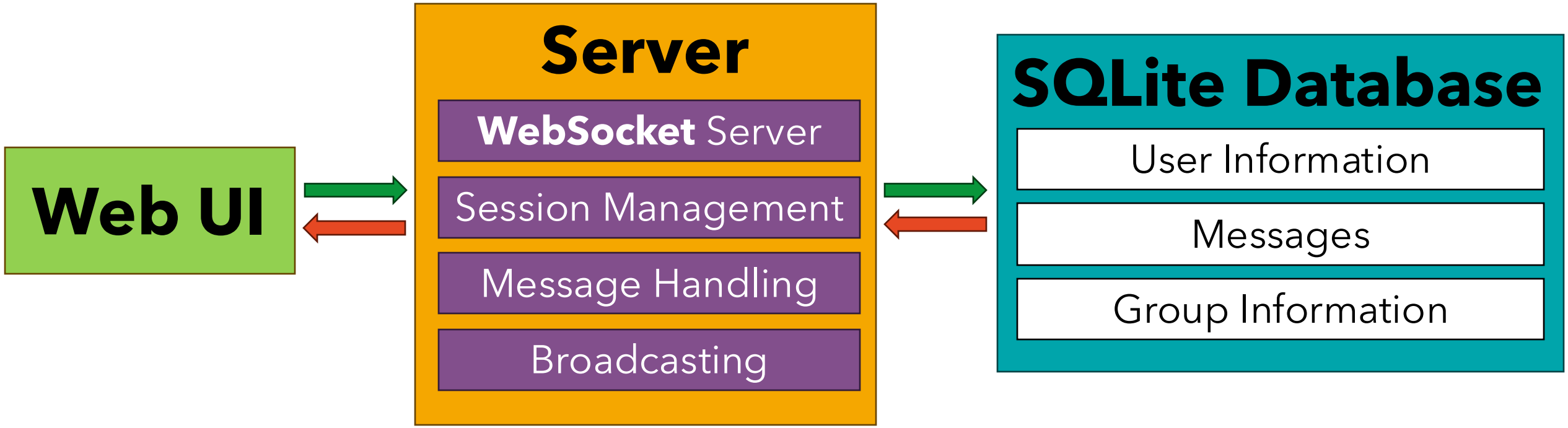
Concepts

Bob Liu Boyu

Architecture Overview



*Passwords are hashed before being stored, and salt values are used to enhance security.

Features

Huo Yuxin

Features

- user management
- messaging functions
- group management
- Web - based Frontend

Features

User management

- Registration
- Login
- Track of online status
- Encrypt passwords

Messaging functions

- Public
- Private
- Group

Group management

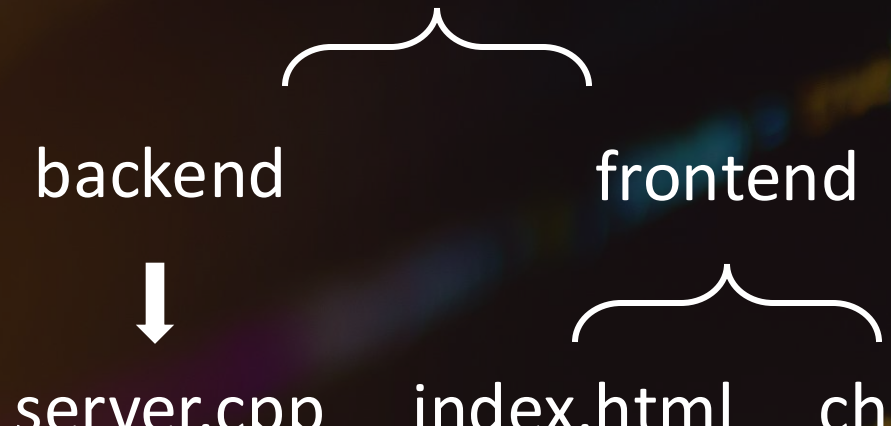
- Create groups
- Add and remove members
- View the composition
- Get historical messages

Web - based Frontend

Implementation

Jara Jiang Yunxin

Implementation



Backend

server.cpp { **Database**, **Security**, **Network Communication**

1. Design a database

- ***users***: stores user login information
- ***messages***: stores private and public chat messages
- ***groups***: stores the owner of the group
- ***group_members***: tracks group memberships
- ***group_messages***: stores group chat history

Automatically delete related members/messages when a group is removed.

Purpose: achieve structured storage, the data will not be lost even if the server is restarted.

```
/*table*/
exec_sql("CREATE TABLE IF NOT EXISTS users ("
         " username TEXT PRIMARY KEY,"
         " salt     BLOB NOT NULL,"    // 16 bytes
         " hash     BLOB NOT NULL);"); // 32 bytes SHA-256

exec_sql("CREATE TABLE IF NOT EXISTS messages ("
         " id        INTEGER PRIMARY KEY AUTOINCREMENT,"
         " sender    TEXT,"
         " receiver  TEXT," // 'all' Express public
         " message   TEXT,"
         " timestamp DATETIME DEFAULT CURRENT_TIMESTAMP);");

exec_sql("CREATE TABLE IF NOT EXISTS groups ("
         " id     INTEGER PRIMARY KEY AUTOINCREMENT,"
         " name   TEXT UNIQUE,"
         " owner  TEXT);");

exec_sql("CREATE TABLE IF NOT EXISTS group_members ("
         " id        INTEGER PRIMARY KEY AUTOINCREMENT,"
         " group_id  INTEGER,"
         " username  TEXT,"
         " is_owner  INTEGER DEFAULT 0,"
         " UNIQUE(group_id,username),"
         " FOREIGN KEY(group_id) REFERENCES groups(id) ON DELETE CASCADE);");

exec_sql("CREATE TABLE IF NOT EXISTS group_messages ("
         " id        INTEGER PRIMARY KEY AUTOINCREMENT,"
         " group_id  INTEGER,"
         " sender    TEXT,"
         " message   TEXT,"
         " timestamp DATETIME DEFAULT CURRENT_TIMESTAMP,"
         " FOREIGN KEY(group_id) REFERENCES groups(id) ON DELETE CASCADE);");
```

2. Security

when a user signs up

⬇

gen_salt() generates a unique random salt

⬇

salt plus password are hashed

⬇

ensure identical passwords from different users produce different hashes

```
std::array<unsigned char, SALT_LEN> gen_salt() {
    std::array<unsigned char, SALT_LEN> s{};
    RAND_bytes(s.data(), SALT_LEN);
    return s;
```

```
std::array<unsigned char, HASH_LEN>
hash_password(const std::array<unsigned char, SALT_LEN> &salt,
              const std::string &password) {
```

```
auto salt = gen_salt();
auto hash = hash_password(salt, p);
```

We don't store the password directly, but store the salt and hash.

⬇

ensure security

2. Security

is_owner:
checks if a user is a group owner who can add or delete users

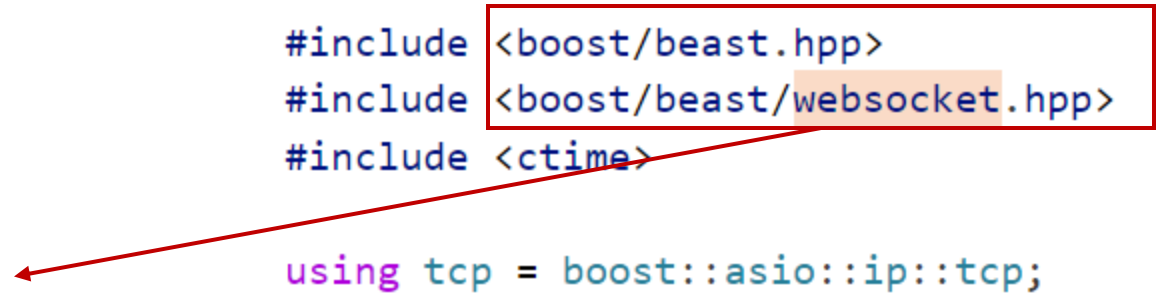
```
bool is_owner(int gid, std::string const &u) {
    sqlite3_stmt *st;
    sqlite3_prepare_v2(g_db,
                       "SELECT is_owner FROM group_members WHERE group_id=? AND username=?;",
                       -1, &st, 0);

    sqlite3_prepare_v2(g_db,
                       "INSERT OR IGNORE INTO group_members(group_id,username,is_owner)"
                       " VALUES(?,?,?);",

    sqlite3_prepare_v2(g_db,
                       "SELECT username,is_owner FROM group_members WHERE group_id=?;",
                       -1, &st, nullptr);

    members.push_back({{"username", reinterpret_cast<const char *>(sqlite3_column_text(st, 0))},
                       {"is_owner", sqlite3_column_int(st, 1) != 0}});
```

```
bool user_in_group(int gid, std::string const &u) {
    sqlite3_stmt *st;

        int gid = j.value("group_id", -1);
        if (gid < 0 || !user_in_group(gid, username_))
            return;

            return;
        if (!user_in_group(gid, username_))
            return;

        for (auto &s : g_sessions) {
            if (user_in_group(gid, s->name()))
                s->push_json(gm);
```

user_in_group:
ensures only group members can send or view group messages

3. Network communication

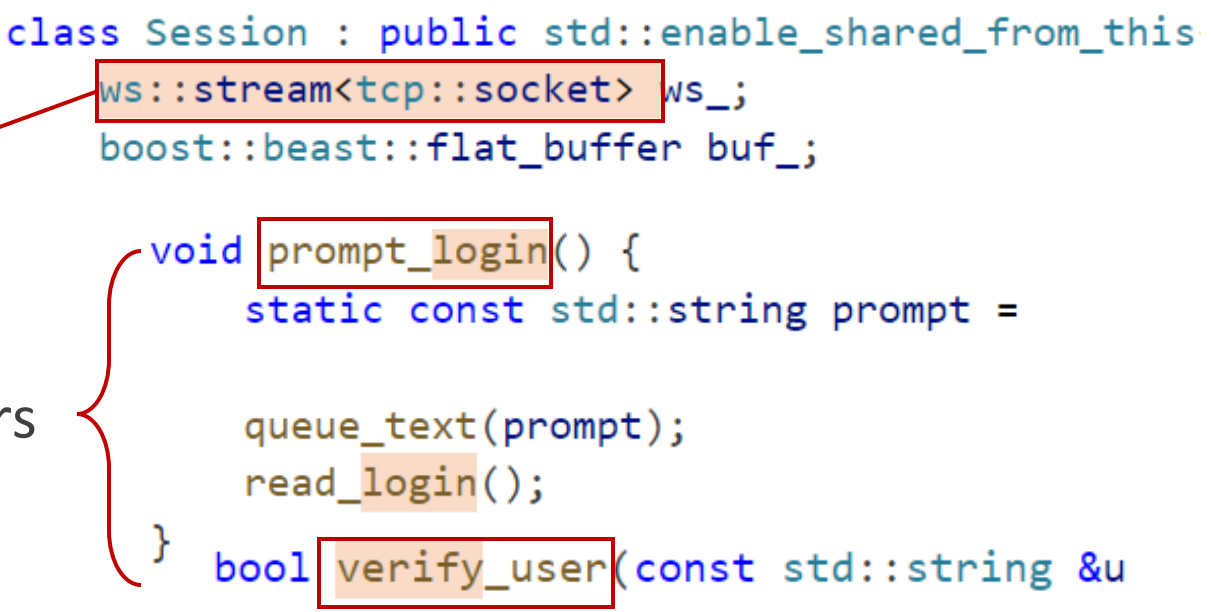
realize asynchronous communication



Core components

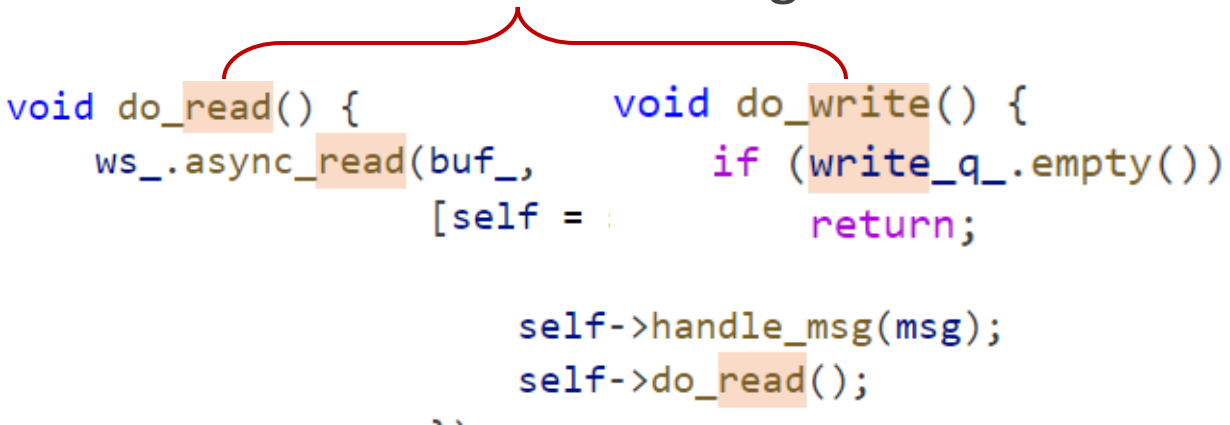
(1) Session Class: manages per-user communication

handles the WebSocket connection



authenticate users

send and receive messages



(2) **Message Handling**

handle_msg: processes different message types:

- Private messages
- Public messages
- Group messages

```
void handle_msg(std::string const &raw) {
    if (!raw.empty() && raw.front() == '{') {
        handle_json(raw);
        return;
    }
void broadcast_json(json const &j) {
    for (auto &s : g_sessions)
        s->push_json(j);
}
```

(3) **Broadcasting**

broadcast_json: sends JSON messages to all online clients (e.g., notifying user list updates)

```
void do_accept(boost::asio::io_context &ioc, tcp::acceptor &acc) {
    acc.async_accept(
        [&](boost::system::error_code ec, tcp::socket sock) {

                std::make_shared<Session>(std::move(sock))->start();
            do_accept(ioc, acc);
        });
```

(4) **Scalability**

do_accept: asynchronously accepts new connections, creating a Session for each.

handle high concurrency and avoid the overhead of thread switching and lock contention

Frontend

- *index.html*: handles the **structure and styling** of the page
- *chat.js*: contains the **core frontend logic**

```
<!-- chatroom/frontend/index.html ├ Telegram style & self bubble blue -->
<!DOCTYPE html>
<html lang="en">

<head>
    <meta charset="UTF-8" />
    <meta http-equiv="X-UA-Compatible" content="IE=edge" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0" />
    <title>Chat Room</title>
    <style>
        /*  ====== Layout ====== */
        body {
            font-family: 'Segoe UI', Arial, 'Microsoft YaHei';
            margin: 0;
            padding: 0;
            display: flex;
            height: 100vh;
            background: □ #e5e5e5;
        }

        #sidebar {
            width: 260px;
            display: flex;
            flex-direction: column;
            background: #fff;
            border-right: 1px solid #ddd;
        }
```

index.html

```
/* ---------------- DOM & State ---------------- */
const ws = new WebSocket('ws://localhost:9002');
const userList = document.getElementById('user-list');
const groupList = document.getElementById('group-list');
const messageContainer = document.getElementById('message-container');
const input = document.getElementById('input');
const sendButton = document.getElementById('send-button');
const connectionStatus = document.getElementById('connection-status');
const chatTarget = document.getElementById('chat-target');
const sidebarTabs = document.querySelectorAll('.sidebar-tab');
const createGroupBtn = document.getElementById('create-group-btn');
const createGroupModal = document.getElementById('create-group-modal');
const manageGroupModal = document.getElementById('manage-members-modal');
const closeButtons = document.querySelectorAll('.close-button, .close-modal');

let myUsername = '';       // write after logging in successfully
let membersRequestPending = false;    // group members request throttling
const avatarColors = new Map();// username -> hsl()

const currentState = {
    targetType: 'room', // room / private / group
    targetId: null,
    targetName: '大厅',
    selectedUser: null,
    selectedGroup: null,
    groups: [],
    onlineUsers: []
};
```

chat.js

Core steps (*chat.js*)

1. Connect Frontend to Backend

```
const ws = new WebSocket('ws://localhost:9002');
```

2. State Management

Use the currentState object to store all states of the current chat interface.
For example, when a user clicks on a group: currentState.targetType = ‘group’

```
const currentState = {
    targetType: 'room', // room / private / group
```

```
        const u = document.getElementById('new-member-input').value.trim();
        if (u && currentState.selectedGroup) {
            ws.send(JSON.stringify({ type: 'add_group_member', group_id: currentState
            document.getElementById('new-member-input').value = '';
```

3. User Operations and Responses

sendMessage() determines the sending logic based on currentState.targetType:

- **Public message**: Send raw text directly.
- **Private message** : Send message in format @username + message content.
- **Group message** : Send JSON object {type: 'group_message', group_id: ..., content: ...}.

```
function sendMessage() {
    const text = input.value.trim(); if (!text) return;

}
sendButton.addEventListener('click', sendMessage);
input.addEventListener('keydown', e => { if (e.key === 'Enter') sendMessage(); });
```

4. UI Rendering

determine if a message
was sent by the current user

```
function isSelfMessage(raw) {
    if (!myUsername) return false;

function appendMessage(raw, type = 'user-msg') {
    const outgoing = (type === 'self-msg' || isSelfMessage(raw));
    const row = document.createElement('div');
```

```
function getAvatarColor(user) {
    if (!avatarColors.has(user))

    avatar.textContent = sender.charAt(0).toUpperCase();
    avatar.style.background = getAvatarColor(sender);
```

generate a unique color
for the sender's avatar

1. clear the current message container
2. add a "History Messages" separator
3. iterate through messages and
call appendMessage() for each

```
function displayHistory(arr) {
    if (!arr || !arr.length) return;

            case 'groups_list': updateGroupsList(j.groups); break;
            case 'history': displayHistory(j.messages); break;
            case 'create_group_response':
```

Demo

Shin Yang Bohan


Thanks for
listening!