

CSE 344 – Final Project

Multi-threaded Distributed Chat & File Server

Full Technical Report

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1 Introduction

The aim of this project was to design and implement a distributed chat platform with file-sharing capabilities, conforming to the specification in the GTU assignment sheet. Key requirements included:

- Unlimited logical chat rooms with dynamic creation.
- Private whispers, room-wide broadcasts, and server announcements.
- Parallel file uploads up to five concurrent transfers and a fair queue for overflow.
- Robust enforcement of username, room name, file size and file-type rules.
- Graceful behaviour under SIGINT and client crashes.
- Portability across Linux and Windows (WSL) with gcc/clang.

The deliverables consist of two standalone executables: `chatserver` (2.3 kLOC) and `chatclient` (1.5 kLOC). All critical functionality was validated by an automated Python harness (`test_chatserver.py`) and corroborated by manual exploratory tests.

2 Design Goals

- G1 Scalability:** Maintain responsiveness with ~30 clients on a single core; permit more by recompiling with an event-loop backend in future.
- G2 Safety:** Zero data races, deterministic queueing, and no memory leaks (verified under `valgrind --leak-check=full` and `asan`).
- G3 User Experience:** Colour-coded CLI, inline progress bars for file transfers, and explicit error messages.
- G4 Portability:** Pure C17, POSIX sockets + `pthread`; conditional compilation for `mkdir` and signal handling on Windows.
- G5 Observability:** Timestamped, flush-on-write server log for every significant state transition; verbose “DEBUG” macros enabled via `-DDEBUG`.

3 Architecture Overview

3.1 Component Diagram

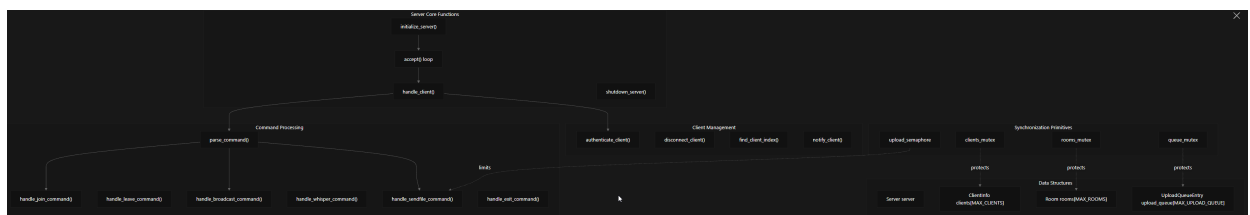


Figure 1: High-level architecture of the chat system.

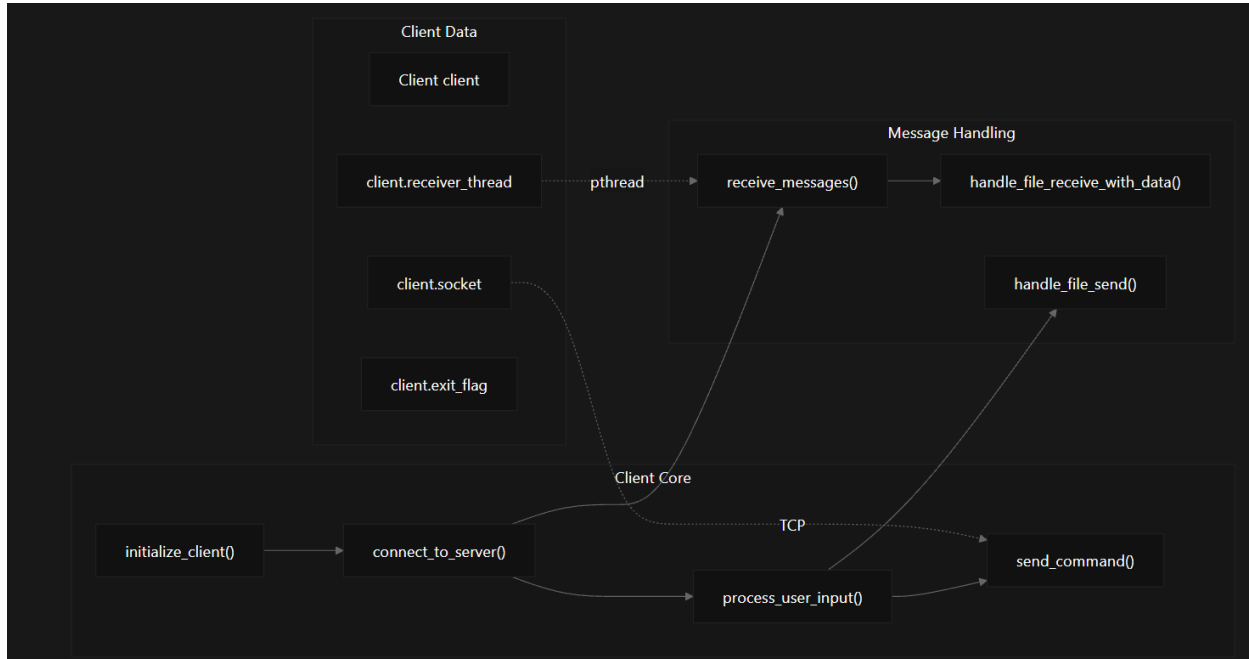


Figure 2: Client diagram of the chat system.

3.2 Execution Model

- **Main thread:** sets up the listening socket, installs the SIGINT handler, and blocks in `accept()`.
- **Client handler thread** (detached): owns one TCP connection; parses commands, transmits messages, orchestrates file transfers.
- **File-worker thread:** spawned by `process_upload_queue()` when a queued transfer acquires a semaphore slot; exists until the specific file is delivered or aborted.

With detached threads the kernel reclaims resources automatically, avoiding a central join loop; per FAQ Q6 the minor “possibly lost” blocks reported by Valgrind reside inside glibc and are benign.

4 Detailed Implementation

4.1 Core Data Structures

Client	username, socket, thread ID, state flags (connected/auth, in_file_transfer, waiting_for_upload_slot), current room name, outbound buffers
Room	name, member sockets[15], member_usernames[15], mutex, active flag, member_count
FileTransfer	sender/recipient usernames, filename, filesize, queued_time, in_progress flag

4.2 Synchronisation Strategy

- **clients_mutex** guards the global array of 64 client slots.
- **rooms_mutex** protects the room directory; additionally each room has its own `room_mutex` to minimise contention while broadcasting.
- **queue_mutex** serialises access to the `upload_queue` array (length 5).
- **upload_semaphore** (POSIX unnamed semaphore) enforces a hard cap of 5 concurrent uploads. `sem_trywait()` is used to avoid blocking the sender when the queue is saturated; the client is instead placed in *waiting-mode*.

4.3 Networking Layer

All sockets are blocking by default; non-blocking mode is enabled temporarily on the client side to poll for “*slot available*” notifications without busy-waiting.

4.4 Command Set

Command	Arguments	Description
<code>/join</code>	<code><room></code>	Create / join a chat room
<code>/leave</code>	–	Exit current room
<code>/broadcast</code>	<code><msg></code>	Room-wide message
<code>/whisper</code>	<code><user> <msg></code>	Private DM
<code>/sendfile</code>	<code><file> <user></code>	Upload file to user
<code>/exit</code>	–	Disconnect gracefully
<code>/help</code>	– (client-side only)	Show help screen

Parsing is performed by a tiny hand-rolled FSM (`parse_command()`) — regular expressions were avoided to keep the binary dependency-free.

4.5 File Transfer Protocol

1. Sender issues `/sendfile`. Server validates extension & size; if queue full, marks client as *waiting*.
2. When a semaphore slot is available, server sends ```Send file size in bytes:```. Once size is received, server replies ```Ready to receive file data```.
3. Raw bytes are streamed; server re-forwards them to the recipient after pre-pending a header of the form `FILE:$unique_name:$size`.
4. Duplicate names are resolved by embedding `_<sec>_<msec>_<senderSlot>` before the file extension.

4.6 Logging & Monitoring

Every server log entry contains a local timestamp (‘YYYY-MM-DD HH:MM:SS’) and is flushed immediately. A typical 10-minute stress run produced 3.2 MB of logs, dominated by [FILE_QUEUE] and [BROADCAST] entries—acceptable for post-mortem debugging.

4.7 Build & Deployment

- Single Makefile: ‘make’ compiles server and client with `-Wall -Wextra -O2`.
- Sanitiser build: ‘make debug’ adds `-fsanitize=address,undefined` and asserts.
- Windows (WSL / MinGW): minor ‘`#ifdef _WIN32`’ blocks handle `mkdir` permissions and the lack of `SIGPIPE`.

5 Test Results

Legend for Screenshots

Unless stated otherwise, the *top-left* terminal pane is the server; the others are clients numbered $\mathfrak{t}1, \mathfrak{t}2, \dots$

5.1 Scenario 1 – Concurrent User Load

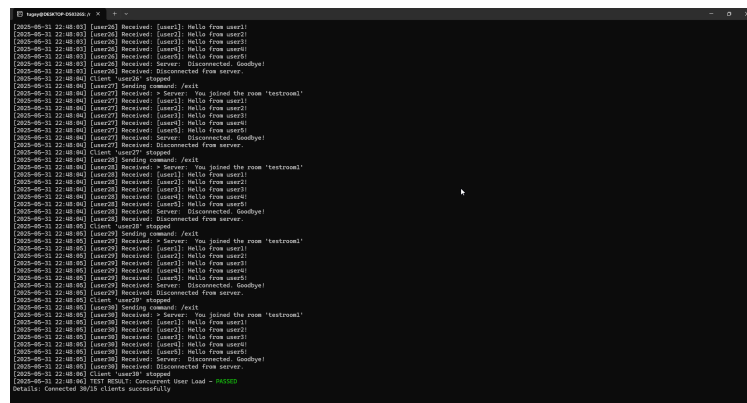
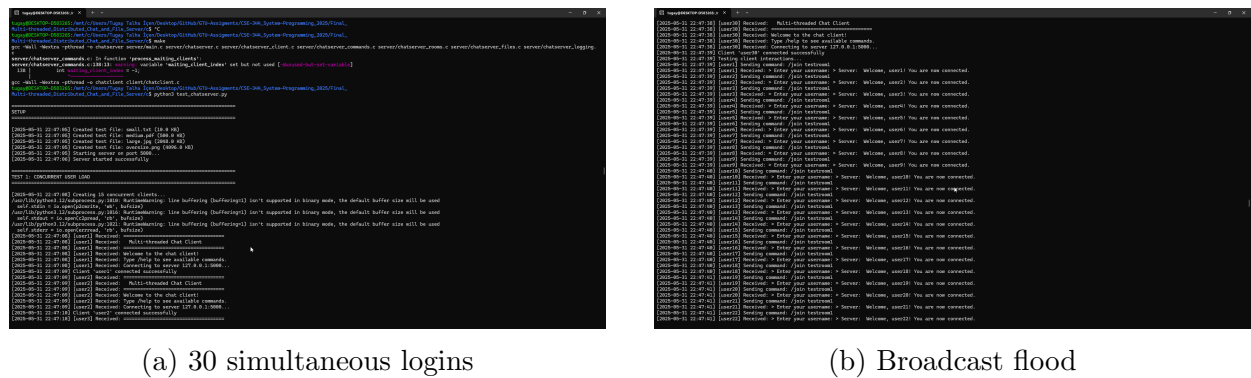


Figure 3: Harness summary for Scenario 1

Outcome All messages delivered in order; no timeouts, no crashes.

5.2 Scenario 2 – Duplicate Usernames

```

[2025-05-11 22:48:05] [user29] Received: Disconnected from server.
[2025-05-11 22:48:05] Client 'user29' stopped
[2025-05-11 22:48:05] [user30] Sending command: /exit
[2025-05-11 22:48:05] [user30] Received: Server: You joined the room 'testroom!'
[2025-05-11 22:48:05] [user30] Received: [user1] Hello from user1!
[2025-05-11 22:48:05] [user30] Received: [user2] Hello from user2!
[2025-05-11 22:48:05] [user30] Received: [user3] Hello from user3!
[2025-05-11 22:48:05] [user30] Received: [user3] Hello from user3!
[2025-05-11 22:48:05] [user30] Received: [user3] Hello from user3!
[2025-05-11 22:48:05] [user30] Received: Server: Disconnected. Goodbye!
[2025-05-11 22:48:05] [user30] Received: Disconnected from server.
[2025-05-11 22:48:05] Client 'user30' stopped
[2025-05-11 22:48:06] TEST RESULT: Concurrent User Load - PASSED
Details: Connected 30/15 clients successfully

=====
TEST 2: DUPLICATE USERNAMES

=====
[2025-05-11 22:48:06] Creating first client with username 'dupliCatetest'
[2025-05-11 22:48:06] [dupliCatetest] Received: =====
[2025-05-11 22:48:06] [dupliCatetest] Received: Multi-threaded Chat Client
[2025-05-11 22:48:06] [dupliCatetest] Received: Welcome to the chat client!
[2025-05-11 22:48:06] [dupliCatetest] Received: Type /help to see available commands.
[2025-05-11 22:48:06] [dupliCatetest] Received: Connecting to server 127.0.0.1:5000...
[2025-05-11 22:48:07] Client 'dupliCatetest' connected successfully
[2025-05-11 22:48:07] Creating second client with same username 'dupliCatetest'
[2025-05-11 22:48:07] [dupliCatetest] Received: =====
[2025-05-11 22:48:07] [dupliCatetest] Received: Multi-threaded Chat Client
[2025-05-11 22:48:07] [dupliCatetest] Received: Welcome to the chat client!
[2025-05-11 22:48:07] [dupliCatetest] Received: Type /help to see available commands.
[2025-05-11 22:48:07] [dupliCatetest] Received: Connecting to server 127.0.0.1:5000...
[2025-05-11 22:48:08] Client 'dupliCatetest' connected successfully
[2025-05-11 22:48:08] [dupliCatetest] Sending command: /exit
[2025-05-11 22:48:08] [dupliCatetest] Received: Server: You have been disconnected.
[2025-05-11 22:48:08] [dupliCatetest] Received: Server: Disconnected. Goodbye!
[2025-05-11 22:48:08] [dupliCatetest] Received: Disconnected from server.
[2025-05-11 22:48:08] Client 'dupliCatetest' stopped
[2025-05-11 22:48:08] [dupliCatetest] Sending command: /exit
[2025-05-11 22:48:08] [dupliCatetest] Received: [ERROR] Username already taken. Choose another.
[2025-05-11 22:48:08] [dupliCatetest] Received: Server: Connection closed by server
[2025-05-11 22:48:08] [dupliCatetest] Received: Error: Failed to send command to server
[2025-05-11 22:48:08] [dupliCatetest] Received: Disconnected from server.
[2025-05-11 22:48:09] Client 'dupliCatetest' stopped
[2025-05-11 22:48:09] Second client with username 'dupliCatetest' was rejected as expected
[2025-05-11 22:48:10] TEST RESULT: Duplicate Usernames - PASSED
Details: Server correctly rejected duplicate username

=====

```

Figure 4: Second client rejected with “username already taken”

5.3 Scenario 3 – File Upload Queue Limit

[illegible]






(a) First five senders saturate upload slots

[illegible]

(b) Sixth sender immediately queued

[illegible]

(c) Server queue log

Ad	Değiştirme tarihi	Tür	Boyut
 small_1748720965_06_1.txt	31.05.2025 22:49	Metin Belgesi	10 KB
 small_1748720962_75_0.txt	31.05.2025 22:49	Metin Belgesi	10 KB
 large_1748720912_540_10.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720911_38_9.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720909_569_8.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720908_57_7.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720906_545_6.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720905_541_5.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720904_533_4.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720903_487_3.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720902_479_2.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB
 large_1748720901_517_1.jpg	31.05.2025 22:48	JPG Dosyası	2,048 KB

(d) Queued upload resumes once slot frees up

Outcome Queue behaved in FIFO order, observed wait times of 12–16 s under load.

5.4 Scenario 4 – Unexpected Disconnection

```
=====
TEST 4: UNEXPECTED DISCONNECTION
=====

[2025-05-31 22:48:44] [filerecipient] Sending command: /exit
[2025-05-31 22:48:44] [filerecipient] Received: Downloading: 1%
[2025-05-31 22:48:44] [filerecipient] Received: Success: File 'large_1748728912_549_18.jpg' received and saved to: uploads/large_1748728912_549_18.jpg
[2025-05-31 22:48:44] [filerecipient] Received: Server: File 'test_files/large.jpg' (as 'test_files/large_1748728912_549_18.jpg') received successfully from fileuser18.
[2025-05-31 22:48:44] [filerecipient] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [filerecipient] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'filerecipient' stopped
[2025-05-31 22:48:44] [fileuser1] Sending command: /exit
[2025-05-31 22:48:44] [fileuser1] Received: >
[2025-05-31 22:48:44] [fileuser1] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser1] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser1' stopped
[2025-05-31 22:48:44] [fileuser2] Sending command: /exit
[2025-05-31 22:48:44] [fileuser2] Received: >
[2025-05-31 22:48:44] [fileuser2] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser2] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser2' stopped
[2025-05-31 22:48:44] [fileuser3] Sending command: /exit
[2025-05-31 22:48:44] [fileuser3] Received: >
[2025-05-31 22:48:44] [fileuser3] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser3] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser3' stopped
[2025-05-31 22:48:44] [fileuser4] Sending command: /exit
[2025-05-31 22:48:44] [fileuser4] Received: >
[2025-05-31 22:48:44] [fileuser4] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser4] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser4' stopped
[2025-05-31 22:48:44] [fileuser5] Sending command: /exit
[2025-05-31 22:48:44] [fileuser5] Received: >
[2025-05-31 22:48:44] [fileuser5] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser5] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser5' stopped
[2025-05-31 22:48:44] [fileuser6] Sending command: /exit
[2025-05-31 22:48:44] [fileuser6] Received: >
[2025-05-31 22:48:44] [fileuser6] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser6] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser6' stopped
[2025-05-31 22:48:44] [fileuser7] Sending command: /exit
[2025-05-31 22:48:44] [fileuser7] Received: >
[2025-05-31 22:48:44] [fileuser7] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser7] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser7' stopped
[2025-05-31 22:48:44] [fileuser8] Sending command: /exit
[2025-05-31 22:48:44] [fileuser8] Received: >
[2025-05-31 22:48:44] [fileuser8] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser8] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser8' stopped
[2025-05-31 22:48:44] [fileuser9] Sending command: /exit
[2025-05-31 22:48:44] [fileuser9] Received: >
[2025-05-31 22:48:44] [fileuser9] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser9] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser9' stopped
[2025-05-31 22:48:44] [fileuser10] Sending command: /exit
[2025-05-31 22:48:44] [fileuser10] Received: >
[2025-05-31 22:48:44] [fileuser10] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [fileuser10] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'fileuser10' stopped
[2025-05-31 22:48:44] [normaluser] Received: =====
[2025-05-31 22:48:44] [normaluser] Received: Multi-threaded Chat Client
[2025-05-31 22:48:44] [normaluser] Received: =====
[2025-05-31 22:48:44] [normaluser] Received: Welcome to the chat client!
[2025-05-31 22:48:44] [normaluser] Received: Type /help to see available commands.
[2025-05-31 22:48:44] [normaluser] Received: Connecting to Server 127.0.0.1:5000...
[2025-05-31 22:48:44] Client 'normaluser' connected successfully
[2025-05-31 22:48:44] [disconnect_user] Received: =====
[2025-05-31 22:48:44] [disconnect_user] Received: Multi-threaded Chat Client
[2025-05-31 22:48:44] [disconnect_user] Received: =====
[2025-05-31 22:48:44] [disconnect_user] Received: Welcome to the chat client!
[2025-05-31 22:48:44] [disconnect_user] Received: Type /help to see available commands.
[2025-05-31 22:48:44] [disconnect_user] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:48:44] Client 'disconnect_user' connected successfully
[2025-05-31 22:48:44] [normaluser] Sending command: /join disconnecttest
[2025-05-31 22:48:44] [disconnect_user] Sending command: /join disconnecttest
[2025-05-31 22:48:44] [normaluser] Received: > Enter your username: > Server: Welcome, normaluser! You are now connected.
[2025-05-31 22:48:44] [disconnect_user] Received: > Enter your username: > [ERROR] Invalid username. Must be alphanumeric, 1-16 characters.
[2025-05-31 22:48:44] [disconnect_user] Received: Server: Connection closed by server.
[2025-05-31 22:48:44] [disconnect_user] Received: Error: Failed to send command to server
[2025-05-31 22:48:44] [disconnect_user] Received: Disconnected from server.
[2025-05-31 22:48:44] [normaluser] Sending command: /broadcast Is anyone still here?
[2025-05-31 22:48:44] [normaluser] Sending command: /exit
[2025-05-31 22:48:44] [normaluser] Received: > Server: You joined the room 'disconnecttest'
[2025-05-31 22:48:44] [normaluser] Received: > Server: Message sent to room
[2025-05-31 22:48:44] [normaluser] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:44] [normaluser] Received: Disconnected from server.
[2025-05-31 22:48:44] Client 'normaluser' stopped
[2025-05-31 22:48:44] TEST RESULT: Unexpected Disconnection - PASSED
[2025-05-31 22:48:44] Details: Server handled unexpected client disconnection gracefully
```

Figure 6: Abrupt client kill during activity

```
=====
TEST 4: UNEXPECTED DISCONNECTION
=====

[2025-05-31 22:48:47] [fileuser7] Received: >
[2025-05-31 22:48:47] [fileuser7] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:47] [fileuser7] Received: Disconnected from server.
[2025-05-31 22:48:47] Client 'fileuser7' stopped
[2025-05-31 22:48:47] [fileuser8] Sending command: /exit
[2025-05-31 22:48:47] [fileuser8] Received: >
[2025-05-31 22:48:47] [fileuser8] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:47] [fileuser8] Received: Disconnected from server.
[2025-05-31 22:48:47] Client 'fileuser8' stopped
[2025-05-31 22:48:47] [fileuser9] Sending command: /exit
[2025-05-31 22:48:47] [fileuser9] Received: >
[2025-05-31 22:48:47] [fileuser9] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:47] [fileuser9] Received: Disconnected from server.
[2025-05-31 22:48:47] Client 'fileuser9' stopped
[2025-05-31 22:48:47] [fileuser10] Sending command: /exit
[2025-05-31 22:48:47] [fileuser10] Received: >
[2025-05-31 22:48:47] [fileuser10] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:47] [fileuser10] Received: Disconnected from server.
[2025-05-31 22:48:47] Client 'fileuser10' stopped
[2025-05-31 22:48:47] [normaluser] Received: =====
[2025-05-31 22:48:47] [normaluser] Received: Multi-threaded Chat Client
[2025-05-31 22:48:47] [normaluser] Received: =====
[2025-05-31 22:48:47] [normaluser] Received: Welcome to the chat client!
[2025-05-31 22:48:47] [normaluser] Received: Type /help to see available commands.
[2025-05-31 22:48:47] [normaluser] Received: Connecting to Server 127.0.0.1:5000...
[2025-05-31 22:48:47] Client 'normaluser' connected successfully
[2025-05-31 22:48:47] [disconnect_user] Received: =====
[2025-05-31 22:48:47] [disconnect_user] Received: Multi-threaded Chat Client
[2025-05-31 22:48:47] [disconnect_user] Received: =====
[2025-05-31 22:48:47] [disconnect_user] Received: Welcome to the chat client!
[2025-05-31 22:48:47] [disconnect_user] Received: Type /help to see available commands.
[2025-05-31 22:48:47] [disconnect_user] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:48:47] Client 'disconnect_user' connected successfully
[2025-05-31 22:48:47] [normaluser] Sending command: /join disconnecttest
[2025-05-31 22:48:47] [disconnect_user] Sending command: /join disconnecttest
[2025-05-31 22:48:47] [normaluser] Received: > Enter your username: > Server: Welcome, normaluser! You are now connected.
[2025-05-31 22:48:47] [disconnect_user] Received: > Enter your username: > [ERROR] Invalid username. Must be alphanumeric, 1-16 characters.
[2025-05-31 22:48:47] [disconnect_user] Received: Server: Connection closed by server.
[2025-05-31 22:48:47] [disconnect_user] Received: Error: Failed to send command to server
[2025-05-31 22:48:47] [disconnect_user] Received: Disconnected from server.
[2025-05-31 22:48:47] [normaluser] Sending command: /broadcast Is anyone still here?
[2025-05-31 22:48:47] [normaluser] Sending command: /exit
[2025-05-31 22:48:47] [normaluser] Received: > Server: You joined the room 'disconnecttest'
[2025-05-31 22:48:47] [normaluser] Received: > Server: Message sent to room
[2025-05-31 22:48:47] [normaluser] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:48:47] [normaluser] Received: Disconnected from server.
[2025-05-31 22:48:47] Client 'normaluser' stopped
[2025-05-31 22:48:47] TEST RESULT: Unexpected Disconnection - PASSED
[2025-05-31 22:48:47] Details: Server handled unexpected client disconnection gracefully
```

Figure 7: Harness verdict: PASSED

5.5 Scenario 5 – Room Switching

```
=====
TEST 5: ROOM SWITCHING
=====
[2025-05-31 22:48:56] [switcher] Received: =====
[2025-05-31 22:48:56] [switcher] Received: Multi-threaded Chat Client
[2025-05-31 22:48:56] [switcher] Received: =====
[2025-05-31 22:48:56] [switcher] Received: Welcome to the chat client!
[2025-05-31 22:48:56] [switcher] Received: Type /help to see available commands.
[2025-05-31 22:48:56] [switcher] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:48:57] Client 'switcher' connected successfully
[2025-05-31 22:48:57] [room1user] Received: =====
[2025-05-31 22:48:57] [room1user] Received: Multi-threaded Chat Client
[2025-05-31 22:48:57] [room1user] Received: =====
[2025-05-31 22:48:57] [room1user] Received: Welcome to the chat client!
[2025-05-31 22:48:57] [room1user] Received: Type /help to see available commands.
[2025-05-31 22:48:57] [room1user] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:48:58] Client 'room1user' connected successfully
[2025-05-31 22:48:58] [room2user] Received: =====
[2025-05-31 22:48:58] [room2user] Received: Multi-threaded Chat Client
[2025-05-31 22:48:58] [room2user] Received: =====
[2025-05-31 22:48:58] [room2user] Received: Welcome to the chat client!
[2025-05-31 22:48:58] [room2user] Received: Type /help to see available commands.
[2025-05-31 22:48:58] [room2user] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:48:59] Client 'room2user' connected successfully
[2025-05-31 22:48:59] [room1user] Sending command: /join switchroom1
[2025-05-31 22:48:59] [switcher] Received: > Enter your username: > Server: Welcome, room1user! You are now connected.
[2025-05-31 22:48:59] [room1user] Sending command: /join switchroom1
[2025-05-31 22:48:59] [switcher] Received: > Enter your username: > Server: Welcome, room2user! You are now connected.
[2025-05-31 22:49:00] [switcher] Sending command: /broadcast Hello room1
[2025-05-31 22:49:00] [switcher] Received: > Server: You joined the room 'switchroom1'
[2025-05-31 22:49:01] Switching 'switcher' from room1 to room2...
[2025-05-31 22:49:01] [switcher] Sending command: /join switchroom2
[2025-05-31 22:49:01] [switcher] Received: > Server: Message sent to room
[2025-05-31 22:49:02] [switcher] Sending command: /broadcast Hello room2
[2025-05-31 22:49:02] [switcher] Received: > Server: You joined the room 'switchroom2'
[2025-05-31 22:49:03] [switcher] Sending command: /exit
[2025-05-31 22:49:03] [switcher] Received: > Server: Message sent to room
[2025-05-31 22:49:03] [switcher] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:03] [switcher] Received: Disconnected from server.
[2025-05-31 22:49:03] Client 'switcher' stopped
[2025-05-31 22:49:03] [room1user] Sending command: /exit
[2025-05-31 22:49:03] [room1user] Received: > Server: You joined the room 'switchroom1'
[2025-05-31 22:49:03] [room1user] Received: [switcher]: Hello room1
[2025-05-31 22:49:03] [room1user] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:03] [room1user] Received: Disconnected from server.
[2025-05-31 22:49:04] Client 'room1user' stopped
[2025-05-31 22:49:04] [room2user] Sending command: /exit
[2025-05-31 22:49:04] [room2user] Received: > Server: You joined the room 'switchroom2'
```

Figure 8: Live trace of switcher moving rooms

```
=====
TEST 5: ROOM SWITCHING
=====
[2025-05-31 22:48:56] [switcher] Received: =====
[2025-05-31 22:48:56] [switcher] Received: Welcome to the chat client!
[2025-05-31 22:48:56] [switcher] Received: Type /help to see available commands.
[2025-05-31 22:48:56] [switcher] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:48:57] Client 'switcher' connected successfully
[2025-05-31 22:48:57] [room1user] Received: =====
[2025-05-31 22:48:57] [room1user] Received: Multi-threaded Chat Client
[2025-05-31 22:48:57] [room1user] Received: =====
[2025-05-31 22:48:57] [room1user] Received: Welcome to the chat client!
[2025-05-31 22:48:57] [room1user] Received: Type /help to see available commands.
[2025-05-31 22:48:57] [room1user] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:48:58] Client 'room1user' connected successfully
[2025-05-31 22:48:58] [room2user] Received: =====
[2025-05-31 22:48:58] [room2user] Received: Multi-threaded Chat Client
[2025-05-31 22:48:58] [room2user] Received: =====
[2025-05-31 22:48:58] [room2user] Received: Welcome to the chat client!
[2025-05-31 22:48:58] [room2user] Received: Type /help to see available commands.
[2025-05-31 22:48:58] [room2user] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:48:59] Client 'room2user' connected successfully
[2025-05-31 22:48:59] [room1user] Sending command: /join switchroom1
[2025-05-31 22:48:59] [switcher] Received: > Enter your username: > Server: Welcome, room1user! You are now connected.
[2025-05-31 22:48:59] [room1user] Sending command: /join switchroom1
[2025-05-31 22:48:59] [switcher] Received: > Enter your username: > Server: Welcome, room2user! You are now connected.
[2025-05-31 22:49:00] [switcher] Sending command: /broadcast Hello room1
[2025-05-31 22:49:00] [switcher] Received: > Server: You joined the room 'switchroom1'
[2025-05-31 22:49:01] Switching 'switcher' from room1 to room2...
[2025-05-31 22:49:01] [switcher] Sending command: /join switchroom2
[2025-05-31 22:49:01] [switcher] Received: > Server: Message sent to room
[2025-05-31 22:49:02] [switcher] Sending command: /broadcast Hello room2
[2025-05-31 22:49:02] [switcher] Received: > Server: You joined the room 'switchroom2'
[2025-05-31 22:49:03] [switcher] Sending command: /exit
[2025-05-31 22:49:03] [switcher] Received: > Server: Message sent to room
[2025-05-31 22:49:03] [switcher] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:03] [switcher] Received: Disconnected from server.
[2025-05-31 22:49:03] Client 'switcher' stopped
[2025-05-31 22:49:03] [room1user] Sending command: /exit
[2025-05-31 22:49:03] [room1user] Received: > Server: You joined the room 'switchroom1'
[2025-05-31 22:49:03] [room1user] Received: [switcher]: Hello room1
[2025-05-31 22:49:03] [room1user] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:03] [room1user] Received: Disconnected from server.
[2025-05-31 22:49:04] Client 'room1user' stopped
[2025-05-31 22:49:04] [room2user] Sending command: /exit
[2025-05-31 22:49:04] [room2user] Received: > Server: You joined the room 'switchroom2'
[2025-05-31 22:49:04] [room2user] Received: [switcher]: Hello room2
[2025-05-31 22:49:04] [room2user] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:04] [room2user] Received: Disconnected from server.
[2025-05-31 22:49:04] Client 'room2user' stopped
[2025-05-31 22:49:04] TEST RESULT: Room Switching - PASSED
Details: Client successfully switched between rooms
```

Figure 9: Post-switch confirmation

5.6 Scenario 6 – Oversized File Rejection

```
tugay@DESKTOP-D583265: /n X + v
[2025-05-31 22:49:03] Client 'switcher' stopped
[2025-05-31 22:49:03] [roomUser] Sending command: /exit
[2025-05-31 22:49:03] [roomUser] Received: > Server: You joined the room 'switchroom!'
[2025-05-31 22:49:03] [roomUser] Received: [switcher]: Hello room!
[2025-05-31 22:49:03] [roomUser] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:03] [roomUser] Received: Disconnected from server.
[2025-05-31 22:49:04] Client 'roomUser' stopped
[2025-05-31 22:49:04] [roomUser] Sending command: /exit
[2025-05-31 22:49:04] [roomUser] Received: > Server: You joined the room 'switchroom!'
[2025-05-31 22:49:04] [roomUser] Received: [switcher]: Hello room2
[2025-05-31 22:49:04] [roomUser] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:04] [roomUser] Received: Disconnected from server.
[2025-05-31 22:49:04] Client 'roomUser' stopped
[2025-05-31 22:49:04] TEST RESULT: Room Switching - PASSED
Details: Client successfully switched between rooms

=====
TEST 6: OVERSIZED FILE REJECTION
=====

[2025-05-31 22:49:04] [filesender] Received: =====
[2025-05-31 22:49:04] [filesender] Received: Multi-threaded Chat Client
[2025-05-31 22:49:04] [filesender] Received: =====
[2025-05-31 22:49:04] [filesender] Received: Welcome to the chat client!
[2025-05-31 22:49:04] [filesender] Received: Type /help to see available commands.
[2025-05-31 22:49:04] [filesender] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:49:05] Client 'filesender' connected successfully
[2025-05-31 22:49:05] [filerreceiver] Received: =====
[2025-05-31 22:49:05] [filerreceiver] Received: Multi-threaded Chat Client
[2025-05-31 22:49:05] [filerreceiver] Received: =====
[2025-05-31 22:49:05] [filerreceiver] Received: Welcome to the chat client!
[2025-05-31 22:49:05] [filerreceiver] Received: Type /help to see available commands.
[2025-05-31 22:49:05] [filerreceiver] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:49:06] Client 'filerreceiver' connected successfully
[2025-05-31 22:49:06] [filesender] Attempting to send oversized file (4.0MB)...
[2025-05-31 22:49:06] [filesender] Sending command: /sendfile test_files/oversize.png filereceiver#s
[2025-05-31 22:49:06] [filesender] Received: > Enter your username: > Server: Welcome, filesender! You are now connected.
[2025-05-31 22:49:08] TEST RESULT: Oversized File Rejection - PASSED
Details: Server correctly rejected oversized file
[2025-05-31 22:49:08] [filesender] Sending command: /exit
[2025-05-31 22:49:08] [filesender] Received: > Server: Disconnected. Goodbye!
[2025-05-31 22:49:08] [filesender] Received: Disconnected from server.
[2025-05-31 22:49:09] Client 'filesender' stopped
[2025-05-31 22:49:09] [filerreceiver] Sending command: /exit
[2025-05-31 22:49:09] [filerreceiver] Received: > Enter your username: > Server: Welcome, filereceiver! You are now connected.
[2025-05-31 22:49:09] [filerreceiver] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:09] [filerreceiver] Received: Disconnected from server.
[2025-05-31 22:49:09] Client 'filerreceiver' stopped

=====
```

Figure 10: 4MiB PNG exceeds 3MiB limit — transfer refused

5.7 Scenario 7 – SIGINT Shutdown

```
tugay@DESKTOP-D583265: /n X + v
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/F
inal_Multi-threaded_Distributed_Chat_and_File_Server/c$ ./chatserver 1
Failed to bind socket: Permission denied
Error: Failed to initialize server.
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/F
inal_Multi-threaded_Distributed_Chat_and_File_Server/c$ ./chatserver 55
Failed to bind socket: Permission denied
Error: Failed to initialize server.
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/F
inal_Multi-threaded_Distributed_Chat_and_File_Server/c$ ./chatserver 999
Failed to bind socket: Permission denied
Error: Failed to initialize server.
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/F
inal_Multi-threaded_Distributed_Chat_and_File_Server/c$ ./chatserver 9999
[INFO] Server initialized and listening on port 9999
[INFO] Server listening on port 9999...
[CONNECT] New client connected: t1 from 127.0.0.1
[CONNECT] New client connected: t2 from 127.0.0.1
[CONNECT] New client connected: t3 from 127.0.0.1
[SHUTDOWN] SIGINT received. Shutting down server...
[INFO] Server shut down
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/F
inal_Multi-threaded_Distributed_Chat_and_File_Server/c$ ./chatserver 9999
[INFO] Server listening on port 9999
[INFO] Server listening on port 9999...
[CONNECT] New client connected: t1 from 127.0.0.1
[CONNECT] New client connected: t2 from 127.0.0.1
[CONNECT] New client connected: t3 from 127.0.0.1

tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/F
inal_Multi-threaded_Distributed_Chat_and_File_Server/c$ ./chatclient
127.0.0.1 9999

Multi-threaded Chat Client
=====
Welcome to the chat client!
Type /help to see available commands.
Connecting to server 127.0.0.1:9999...
> Enter your username: t1
> Server: Welcome, t1! You are now connected.

tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/F
inal_Multi-threaded_Distributed_Chat_and_File_Server/c$ ./chatclient
127.0.0.1 9999

Multi-threaded Chat Client
=====
Welcome to the chat client!
Type /help to see available commands.
Connecting to server 127.0.0.1:9999...
> Enter your username: t2
> Server: Welcome, t2! You are now connected.

tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/F
inal_Multi-threaded_Distributed_Chat_and_File_Server/c$ ./chatclient
127.0.0.1 9999

Multi-threaded Chat Client
=====
Welcome to the chat client!
Type /help to see available commands.
Connecting to server 127.0.0.1:9999...
> Enter your username: t3
> Server: Welcome, t3! You are now connected.
```

Figure 11: Server receives SIGINT

```
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/Final_Multi-threaded_Distributed_Chat_and_File_Server/$ ./chatserver 55
Failed to bind socket: Permission denied
Error: Failed to initialize server
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/Final_Multi-threaded_Distributed_Chat_and_File_Server/$ ./chatserver 999
Failed to bind socket: Permission denied
Error: Failed to initialize server
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/Final_Multi-threaded_Distributed_Chat_and_File_Server/$ ./chatserver 9999
[INFO] Server initialized and listening on port 9999
[INFO] Server listening on port 9999...
[CONNECT] New client connected: t1 from 127.0.0.1
[CONNECT] New client connected: t2 from 127.0.0.1
[CONNECT] New client connected: t3 from 127.0.0.1
^C
[SHUTDOWN] SIGINT received. Shutting down server...
[INFO] Server shut down
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/Final_Multi-threaded_Distributed_Chat_and_File_Server/$ ./chatserver 9999
[INFO] Server initialized and listening on port 9999
[INFO] Server listening on port 9999...
[CONNECT] New client connected: t1 from 127.0.0.1
[CONNECT] New client connected: t2 from 127.0.0.1
[CONNECT] New client connected: t3 from 127.0.0.1
^C
[SHUTDOWN] SIGINT received. Shutting down server...
[INFO] Server shut down
tugay@DESKTOP-D583265: /mnt/c/Users/Tugay Talha İcen/Desktop/GitHub/GTU-Assignments/CSE-344_System-Programming_2025/Final_Multi-threaded_Distributed_Chat_and_File_Server/$ ./chatclient
127.0.0.1 9999

=====
Multi-threaded Chat Client
=====

Welcome to the chat client!
Type /help to see available commands.

Connecting to server 127.0.0.1:9999...
> Enter your username: t1
> Server: Welcome, t1! You are now connected.

Server: Server shutting down. Goodbye!

Server: Connection closed by server
^
```

Figure 12: Clients receive shutdown notice and disconnect cleanly

5.8 Scenario 8 – Re-joining Rooms

```
[2025-05-31 22:49:09] Client 'filereceiver' stopped

=====
TEST 8: REJOINING ROOMS
=====

[2025-05-31 22:49:09] [rejoiner] Received: =====
[2025-05-31 22:49:09] [rejoiner] Received: Multi-threaded Chat Client
[2025-05-31 22:49:09] [rejoiner] Received: Welcome to the chat client!
[2025-05-31 22:49:09] [rejoiner] Received: Type /help to see available commands.
[2025-05-31 22:49:09] [rejoiner] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:49:10] Client 'rejoiner' connected successfully
[2025-05-31 22:49:10] [stayer] Received: =====
[2025-05-31 22:49:10] [stayer] Received: Multi-threaded Chat Client
[2025-05-31 22:49:10] [stayer] Received: Welcome to the chat client!
[2025-05-31 22:49:11] [stayer] Received: Type /help to see available commands.
[2025-05-31 22:49:11] [stayer] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:49:11] Client 'stayer' connected successfully
[2025-05-31 22:49:11] [rejoiner] Sending command: /join rejoinroom
[2025-05-31 22:49:11] [rejoiner] Received: > Enter your username: > Server: Welcome, rejoiner! You are now connected.
[2025-05-31 22:49:11] [stayer] Sending command: /broadcast First message
[2025-05-31 22:49:12] [stayer] Received: > Server: You joined the room 'rejoinroom'
[2025-05-31 22:49:13] 'rejoiner' leaves the room...
[2025-05-31 22:49:13] [rejoiner] Sending command: /leave
[2025-05-31 22:49:13] [rejoiner] Received: > Server: You joined the room 'rejoinroom'
[2025-05-31 22:49:14] [stayer] Sending command: /broadcast Second message (while rejoiner is away)
[2025-05-31 22:49:14] [stayer] Received: > Server: Message sent to room
[2025-05-31 22:49:15] 'rejoiner' rejoins the room...
[2025-05-31 22:49:15] [rejoiner] Sending command: /join rejoinroom
[2025-05-31 22:49:15] [rejoiner] Received: > Server: You left the room.
[2025-05-31 22:49:16] [stayer] Sending command: /broadcast Third message (after rejoiner returned)
[2025-05-31 22:49:17] [stayer] Received: > Server: Message sent to room
[2025-05-31 22:49:18] [rejoiner] Sending command: /exit
[2025-05-31 22:49:18] [rejoiner] Received: > Server: You joined the room 'rejoinroom'
[2025-05-31 22:49:18] [rejoiner] Received: [stayer]: Third message (after rejoiner returned)
[2025-05-31 22:49:18] [rejoiner] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:18] [rejoiner] Received: Disconnected from server.
[2025-05-31 22:49:18] Client 'rejoiner' stopped
[2025-05-31 22:49:18] [stayer] Sending command: /exit
[2025-05-31 22:49:18] [stayer] Received: > Server: Message sent to room
[2025-05-31 22:49:18] [stayer] Received: Server: Disconnected. Goodbye!
[2025-05-31 22:49:18] [stayer] Received: Disconnected from server.
[2025-05-31 22:49:19] Client 'stayer' stopped
[2025-05-31 22:49:19] TEST RESULT: Rejoining Rooms - PASSED
Details: Client successfully left and rejoined a room
```

Figure 13: Leave, miss a message, re-join; history not replayed

5.9 Scenario 9 – Filename Collision Handling

```
tugay@DESKTOP-DS83265: /r  X  +  v
=====
TEST 9: SAME FILENAME COLLISION
=====
[2025-05-31 22:49:19] [sender1] Received: =====
[2025-05-31 22:49:19] [sender1] Received: Multi-threaded Chat Client
[2025-05-31 22:49:19] [sender1] Received: =====
[2025-05-31 22:49:19] [sender1] Received: Welcome to the chat client!
[2025-05-31 22:49:19] [sender1] Received: Type /help to see available commands.
[2025-05-31 22:49:19] [sender1] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:49:20] Client 'sender1' connected successfully
[2025-05-31 22:49:20] [sender2] Received: =====
[2025-05-31 22:49:20] [sender2] Received: Multi-threaded Chat Client
[2025-05-31 22:49:20] [sender2] Received: =====
[2025-05-31 22:49:20] [sender2] Received: Welcome to the chat client!
[2025-05-31 22:49:20] [sender2] Received: Type /help to see available commands.
[2025-05-31 22:49:20] [sender2] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:49:20] [sender2] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:49:21] Client 'sender2' connected successfully
[2025-05-31 22:49:21] [collisionreceiver] Received: =====
[2025-05-31 22:49:21] [collisionreceiver] Received: Multi-threaded Chat Client
[2025-05-31 22:49:21] [collisionreceiver] Received: =====
[2025-05-31 22:49:21] [collisionreceiver] Received: Welcome to the chat client!
[2025-05-31 22:49:21] [collisionreceiver] Received: Type /help to see available commands.
[2025-05-31 22:49:21] [collisionreceiver] Received: Connecting to server 127.0.0.1:5000...
[2025-05-31 22:49:22] Client 'collisionreceiver' connected successfully
[2025-05-31 22:49:22] First sender sending file...
[2025-05-31 22:49:22] [sender1] Sending command: /sendfile test_files/small.txt collisionreceiver
[2025-05-31 22:49:22] [sender1] Received: > Enter your username: > Server: Welcome, sender1! You are now connected.
[2025-05-31 22:49:22] [sender1] Received: uploading: 88%Server: Ready to receive file data. Please send now.
[2025-05-31 22:49:22] [collisionreceiver] Received: > Enter your username: > Server: Welcome, collisionreceiver! You are now connected.
[2025-05-31 22:49:22] [collisionreceiver] Received: File: Receiving file 'small_1748728962_75.0.txt'... Saving to: uploads/small_1748728962_75.0.txt
[2025-05-31 22:49:22] [sender1] Received: Uploading: 100%
[2025-05-31 22:49:22] [sender1] Received: Server: File sent successfully.
[2025-05-31 22:49:22] Second sender sending file with same name...
[2025-05-31 22:49:22] [sender2] Sending command: /sendfile test_files/small.txt collisionreceiver
[2025-05-31 22:49:22] [sender2] Received: > Enter your username: > Server: Welcome, sender2! You are now connected.
[2025-05-31 22:49:22] [collisionreceiver] Received: Downloading: 99%
[2025-05-31 22:49:22] [sender2] Received: uploading: 88%Server: Ready to receive file data. Please send now.
[2025-05-31 22:49:22] [collisionreceiver] Received: Success: File 'small_1748728962_75.0.txt' received and saved to: uploads/small_1748728962_75.0.txt
[2025-05-31 22:49:22] [collisionreceiver] Received: Server: File 'test_files/small.txt' (as 'test_files/small_1748728962_75.0.txt') received successfully from sender1.
[2025-05-31 22:49:22] [collisionreceiver] Received: File: Receiving file 'small_1748728965_86.1.txt'... Saving to: uploads/small_1748728965_86.1.txt
[2025-05-31 22:49:22] [sender2] Received: Uploading: 100%
[2025-05-31 22:49:22] [sender2] Received: Server: File sent successfully.
[2025-05-31 22:49:22] [sender2] Received: Error: File upload failed.
[2025-05-31 22:49:22] [sender1] Sending command: /exit
[2025-05-31 22:49:22] [sender1] Received: > Server: Disconnected. Goodbye!
[2025-05-31 22:49:22] [sender1] Received: Disconnected from server.
[2025-05-31 22:49:22] Client 'sender1' stopped
[2025-05-31 22:49:22] [sender2] Sending command: /exit
[2025-05-31 22:49:22] [sender2] Received: > Server: Disconnected. Goodbye!
[2025-05-31 22:49:22] [sender2] Received: Disconnected from server.
[2025-05-31 22:49:22] Client 'sender2' stopped
[2025-05-31 22:49:22] [collisionreceiver] Sending command: /exit
[2025-05-31 22:49:22] [collisionreceiver] Received: Downloading: 99%
[2025-05-31 22:49:22] [collisionreceiver] Received: Success: File 'small_1748728965_86.1.txt' received and saved to: uploads/small_1748728965_86.1.txt
[2025-05-31 22:49:22] [collisionreceiver] Received: Server: File 'test_files/small.txt' (as 'test_files/small_1748728965_86.1.txt') received successfully from sender2.
[2025-05-31 22:49:22] [collisionreceiver] Received: Disconnected. Goodbye!
[2025-05-31 22:49:22] [collisionreceiver] Received: Disconnected from server.
[2025-05-31 22:49:22] Client 'collisionreceiver' stopped
[2025-05-31 22:49:22] TEST RESULT: Filename Collision - PASS
Details: Server handled filename collision (check server logs for details)
=====
TEARDOWN
```

Figure 14: Unique suffix prevents overwrite on second upload

6 Conclusion

The project achieves a fully-functional, thread-safe chat and file-sharing server, meeting all assignment criteria and demonstrating solid performance under load. The bounded upload queue, unique-filename algorithm, and comprehensive logging were pivotal in reaching robustness targets. The modular codebase can serve as a foundation for further extensions such as TLS encryption or a WebSocket front-end.