Distributed Systems Assignment
Client-server System to Play Poker

Group Members (T12-G15):

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Implementation and Testing

This project was developed using Java SE 21 and Gradle 8.5. The list of dependencies is the following:

- JDBC
- jBCrypt
- JSON
- GSON

Run Server

```
$ gradle server --args="<port> [-l] [-r]"
```

- <port> must be a valid port (e.g.: 8000)
- [-l] is optional and enables logging
- [-r] is optional and enables ranked mode

Run Client

```
$ gradle client --args="<host> <port>"
```

- <host> must be a valid host (e.g.: localhost)
- <port> must be a valid port, (e.g.: 8000)

Database

The database for this system is stored in the `database` folder inside the project `src` folder. We are using a SQLite database.

In order to reset and populate the database with the initial data, run the following command:

```
$ gradle databaseInit
```

The database contains only one table, `User`, capable of storing the following data:

- username (PK)
- password
- rank
- session_token
- session_expiration

For the purpose of streamlining the demonstration and evaluation of this system, the database was pre-populated with the following users:

username	password (on login)	rank
marco	marco	1000
tiago	tiago	2000
ramos	ramos	1000
joao	joao	1500
rita	rita	500
jorge	jorge	0
afonso	afonso	5000
camilla	camilla	5000
baquero	baquero	0
alberto	alberto	0
veronica	veronica	0

The passwords are stored using BCrypt hash with *salt*.

A new token is generated using BCrypt hash with *salt* and the username when the user authenticates, and it is stored in the database. This token is valid for 24 hours.

The token can be used to reconnect to the server without the need to authenticate again.

Communication

The communication between the server and the client is done using a custom message protocol and custom channels. Most of the classes implemented for this purpose are within the `poker.connection.protocol` package.

The communication can be divided into two main components:

- **Messages**
- **Channels**

Messages

Messages are the objects that are sent between the server and the client. They contain 4 important fields:

- **State**: represents the stage of the application in which the message is being sent (e.g.: CONNECTION_END, AUTHENTICATION, MATCH_RECONNECT, etc.)
- **Status**: represents the status of the message (REQUEST, OK, ERROR)
- **Body**: a string that contains direct feedback about the message, usually provided by the server (e.g.: "*User successfully logged in*", etc.).
- **Data**: contains different attributes that are specific to the message being sent (e.g.: username and password, etc.)

These messages are being sent using the JSON format. The GSON library was used for the serialization and deserialization of more complex objects.

Channels

The channels are objects of the abstract class `Channel`. This class is extended by two other classes:

- **ClientChannel**: represents the channel that is used by the client to communicate with the server.
- **ServerChannel**: represents the channel that is used by the server to communicate with the client.

The channel stores the Socket and the associated Input and Output streams, and creates a new layer of abstraction for the communication between both parties.

Channel Exceptions

During the communication process, different types of errors can occur, for a multitude of reasons. In order to classify those errors, many types of exceptions were defined within the `poker.connection.protocol.exceptions` package. These exceptions are thrown when an error occurs and are caught either by the server or the client, depending on the context. They include:

- **ClosedConnectionException**: thrown when the channel is closed.
- **RequestTimeoutException**: thrown when a request times out.
- **TokenMismatchException**: thrown when one of the parties does not recognize the received token.
- **UnexpectedMessageException**: thrown when an unexpected message is received, depending on both the state and the status of the message.

Game

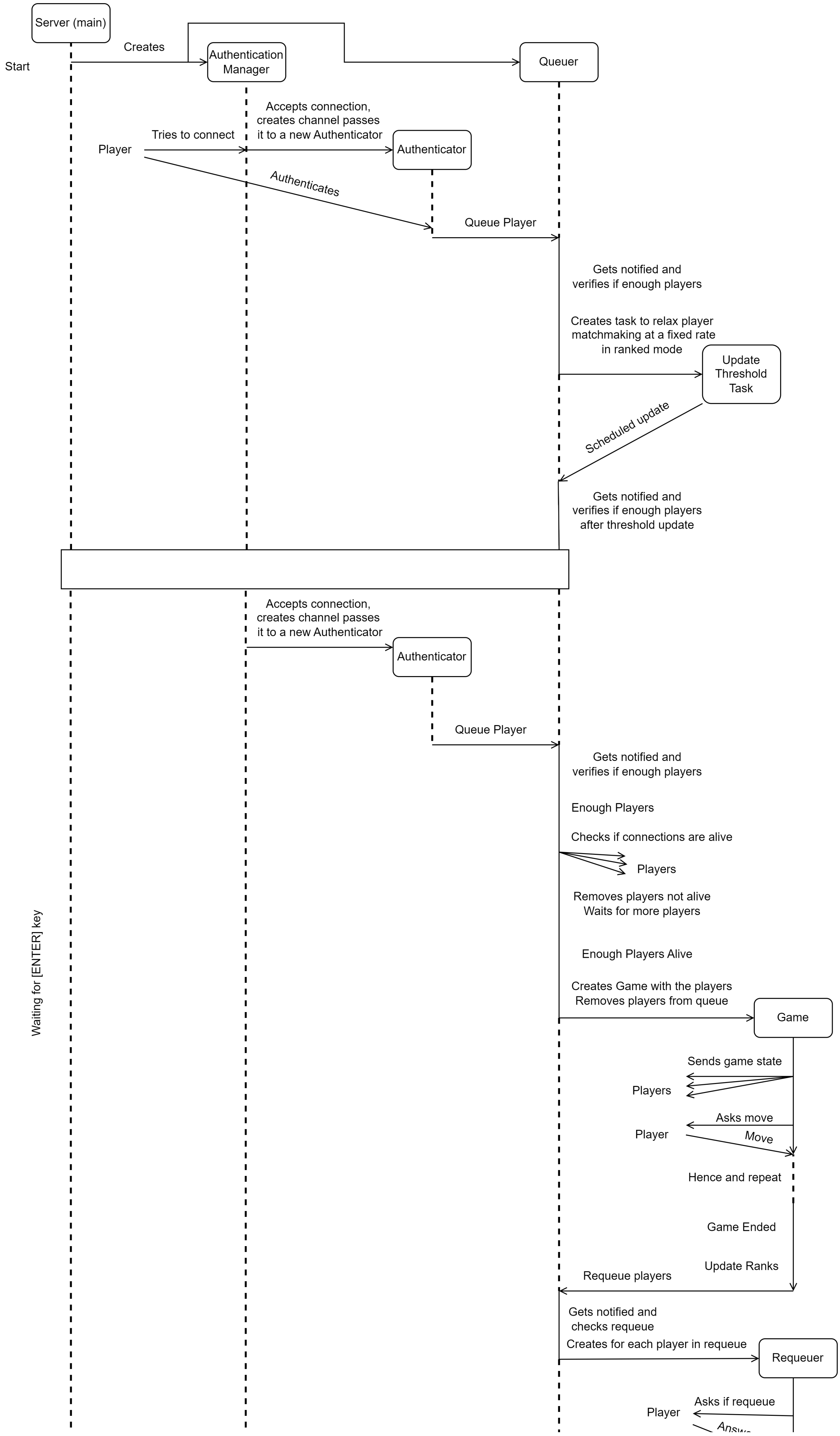
The game is a simple version of "Poker (No Limit) Texas Hold'em" and is played between 6 players/clients (the server being the dealer).

Most of the game logic and model is implemented in the `game` directory.

The number of players (among with other game features) is easily configurable by changing the value of the `NUM_PLAYERS` constant in the `poker.game.common.PokerConstants.java` class.

For easier manipulation of the game by the server, the main class `Poker` represents the current game instance's state.

Architecture


Server (main)
Start
Creates
Authentication Manager
Queuer
Accepts connection, creates channel passes it to a new Authenticator
Tries to connect
Player
Authenticator
Authenticates
Queue Player
Gets notified and verifies if enough players
Creates task to relax player matchmaking at a fixed rate in ranked mode
Update Threshold Task
Scheduled update
Gets notified and verifies if enough players after threshold update
Accepts connection, creates channel passes it to a new Authenticator
Authenticator
Queue Player
Gets notified and verifies if enough players
Enough Players
Checks if connections are alive
Players
Removes players not alive Waits for more players
Enough Players Alive
Creates Game with the players Removes players from queue
Game
Waiting for [ENTER] key
Sends game state
Players
Asks move
Player
Move
Hence and repeat
Game Ended
Update Ranks
Requeue players
Gets notified and checks requeue
Creates for each player in requeue
Requeuer
Asks if requeue
Player

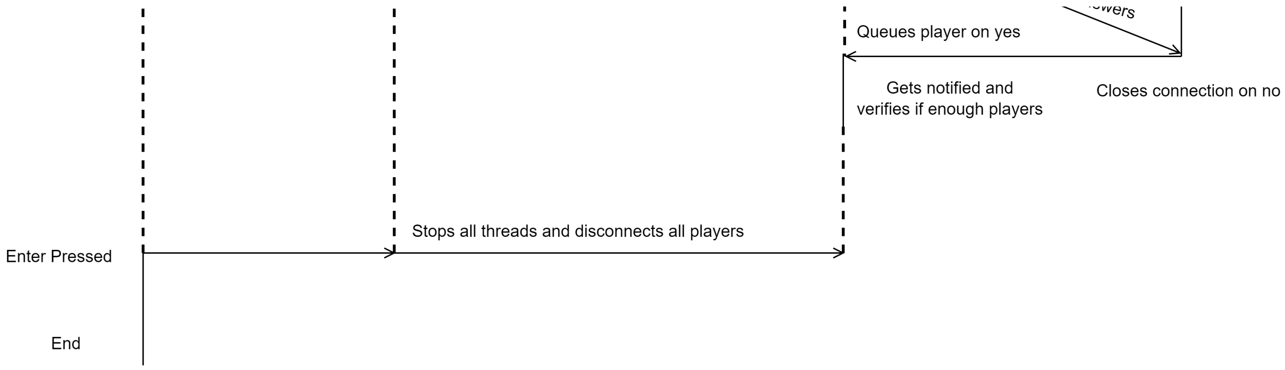

wers
Queues player on yes
Gets notified and verifies if enough players
Closes connection on no
Stops all threads and disconnects all players
Enter Pressed
End

Figure 1 - Simple flow of the program (Reconnections not depicted)

As depicted in Figure 1, there are 3 main threads running in the server application:

- **Server**: responsible for starting the other main threads and closing the server.
- **AuthenticationManager**: responsible for accepting new connections and authenticating users.
- **Queuer**: responsible for managing the queue of players waiting to play and starting games.

This structure allowed for a more organized and efficient way of managing the server application.

The **AuthenticationManager** creates an **Authenticator** thread for each new connection, which is responsible for handling the authentication logic.

The **Queuer** stays in a suspended state until it gets notified. This notification can be triggered by:

- The **Authenticator**, when a user is successfully authenticated.
- The **Game**, when a game is finished.
- The **Requeuer**, when a player wants to requeue.
- The *Task*, responsible for relaxing the matchmaking in ranked mode.

The **Queuer** is extended by the **SimpleQueuer** and **RankedQueuer** classes, which are responsible for managing the queue of players waiting to play in simple and ranked modes, respectively.

When a player is matched with other players, a **Game** thread is created.

The **Game** is responsible for managing the game logic and state, and communicating with the players during the game. For ranked games, the **Game** will also update the players' ranks after the game ends.

The **Requeuer** is responsible for handling the requeue logic and communicating with the players during the requeue process.

If the server is running in ranked mode, the matchmaking algorithm will try to match players who have similar levels, and *tasks* are created to schedule the matchmaking relaxation. A task is responsible for updating the threshold of ranks a player can play with over time, allowing players to be matched with others with a wider rank difference. In order to do this in a way that is congruent with the waiting time (in queue) of the players, a task is scheduled for each player when they enter the queue.

When the **Server** wishes to close, it interrupts all threads running and disconnects all clients.

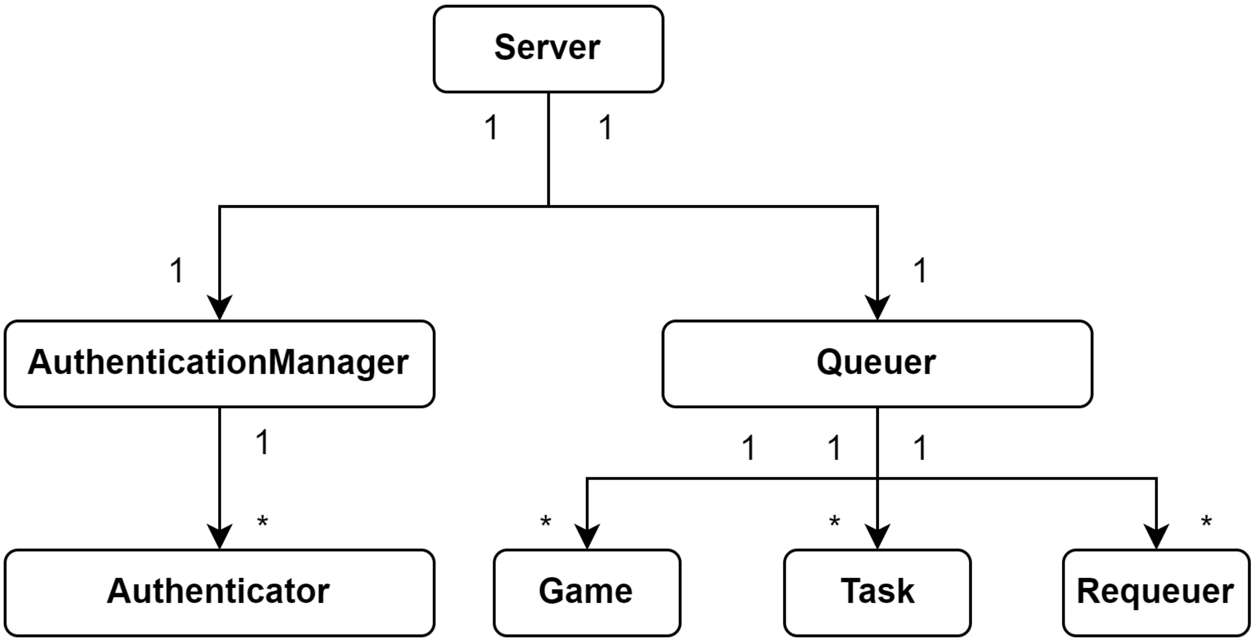


Figure 2 - Thread hierarchy

Figure 2 depicts the hierarchy of the threads in the application.

Secure Channels

As a means of establishing secure communication between both the client and the server, we used **SSLSockets**. **SSLSockets** are an extension of the Socket class, which is used to create a connection between the client and the server.

These sockets provide an additional layer of security to the connection by using the Secure Sockets Layer (SSL) and Transport Layer Security (TLS) protocols. The **SSLSocket** class is used to create a socket that is capable of communicating over a secure connection. To establish a secure connection between the server and the client, the following steps were taken:

A private key was generated for the server.

```
openssl genpkey -algorithm RSA -out server_private_key.pem -pkeyopt
rsa_keygen_bits:2048
```

A certificate signing request was then generated for the server, as well as the subsequent self-signed certificate.

```
openssl req -new -key server_private_key.pem -out server_certificate_request.csr
openssl x509 -req -days 365 -in server_certificate_request.csr -signkey
server_private_key.pem -out server_certificate.pem
```

This certificate was then imported into both the server keystore and the client truststore.

```
openssl pkcs12 -export -in server_certificate.pem -inkey server_private_key.pem -out server_keystore.p12
openssl x509 -outform der -in server_certificate.pem -out server_certificate.cer
keytool -importcert -file server_certificate.cer -alias server-cert -keystore client_truststore.jks -storetype JKS
```

A TLS based SSLContext is created for the server and client, using the server keystore and client truststore respectively. The server and client are then able to establish a secure connection using the **SSLSockets**.

Authentication

Upon starting the client application, a connection is established with the server.

If the user has a user token stored locally, they are asked if they want to reconnect using the token. If the user chooses to reconnect, the token is sent to the server, which checks if the token is valid. If the token is valid, the user is reconnected to the server.

When the token is invalid, the user does not want to use the token or no token existed in the first place, the user is prompted to enter their username and password.

This information is then sent to the server, which checks if the credentials are valid. In that case, the server sends a token back to the client, which is stored locally. The user is then connected to the server.

If the credentials are invalid but the user exists, the user is prompted to enter the credentials again.

If the user does not exist in the system, they are registered in the server and connected afterwards.

Fault Tolerance

The server is able to manage multiple clients at the same time. If a client disconnects, the server is able to handle it and continue running without any issues.

If the client wishes to reconnect, the server is also capable of performing that task. After authenticating the client, the server verifies if they are already in a game or waiting in the queue, allowing the client to retake his place. The old connection is substituted by the new one.

The system we designed has the following characteristics:

- A client can't leave a game and start another one while the first one has not ended.
- When two clients authenticate with the same account, the one that authenticates last is the one with access to the account.
- When something happens to the connection during the game, the client gets disconnected and the default action taken as a player is *fold*.
- The server sends messages to clients before starting the game to check if the connection is alive.

These restrictions allowed for a simpler reconnection process.

Concurrency

Race Conditions

The access to shared resources is controlled by the use of locks. The `ReentrantLock` class was used to implement this mechanism. The locks allow to control the access to the following resources:

- A set of players connected to the server.
- A queue of players waiting to play.
- A queue of players waiting to reenter the queue.
- A map of players to game rooms.

The **set of connections to the server** belongs to the `Server` class and is shared between the `Server` and the `Authenticator` threads. The `Authenticator` adds the connections to this set after the players are authenticated, and then it is used by the `Server` to disconnect clients when the server is closed.

All the remaining data structures belong to the `Queuer` class and are shared between the `Queuer`, the `Requeuer` and the `Game` threads. A player is added to the **main queue** when they are authenticated and the `Queuer` thread is started, and removed from it when they are matched with other players and a `Game` thread starts. The **requeue** is used to store players that want to requeue after a game ends, and the **game rooms** map the players to the game thread they are currently playing in, allowing for a simpler way to reconnect a client to a game.

The synchronization between the threads is done by acquiring the lock before accessing the shared resource and releasing it after the access is done.

Thread Overheads

In order to reduce the overhead inherent to the creation of OS threads, we used Virtual Threads, which are lightweight.

`"Virtual threads are implemented in a similar way to virtual memory. To simulate a lot of memory, an operating system maps a large virtual address space to a limited amount of RAM. Similarly, to simulate a lot of threads, the Java runtime maps a large number of virtual threads to a small number of OS threads."`[1]

Timeouts

The server also has a timeout mechanism that closes the connection to the client if it does not respond to the server's requests within a certain time interval. This mechanism is implemented in the `Channel` class and avoids the server from waiting indefinitely for a response from the client.