SHARED WHITEBOARD

COMP90015 - DISTRIBUTED SYSTEMS
ASSIGNMENT 2

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1 Introduction

The project implemented is related to a shared whiteboard that is capable of handling multiple clients, in which they can perform basic drawing operations and send messages to the group. The application uses a client-server architecture with a thread pool worker and user interface for clients.

2 Problem Context

The problem statement for this application is to create a shared whiteboard in which multiple clients can draw simultaneously. They can use different tools such as free-hand drawing, erasing, drawing different shapes like circles, triangles, and rectangles, and also input text into the drawing area. The clients should also have the facility to chat with the group of clients connected and see the list of active clients. Amongst the clients, one person will be the manager with the ability to perform file operations like open files, save files, and new files. The manager should also have the ability to remove users from the shared whiteboard and new clients joining should only be allowed once the manager accepts the join request.

3 Server Architecture

3.1 Whiteboard Server

The server is initialized by running the ***WhiteboardServer.java*** file. This is used to open a socket on the port defined by the user and wait for client connections. The client connections are handled by a thread pool. It keeps a track of all the verified and unverified clients connected as well as the client acting as the manager of the shared whiteboard.

3.2 Whiteboard Server Functions

We create a *runnable* interface, ***WhiteboardHandler.java*** file which allows the server to maintain a separate thread for each client connected. It handles various events triggered by both clients and the manager. It allocates the first user connected as the manager and sends a user permission event to the manager for any clients that join after that. It also handles administration tasks like client exit, client removal, user acceptance, and rejection events from the manager. It has the capability of sending direct messages as well as broadcast messages. All the draw and chat events triggered by the clients go through the server and get broadcast to all the active clients. Multiple exception scenarios have been handled in order to keep the whiteboard running smoothly.

3.3 Whiteboard Server Utilities

The server applications make use of several utility classes which have reusable code and help the main code look cleaner and more understandable for further refactoring. ***TypeConversionutils.java*** file helps in converting the requests sent over the network to relevant DTOs[1] for further use. The server also makes use of frequently used constants by accessing the ***Constants.java*** file.

[1]Data Transfer Object

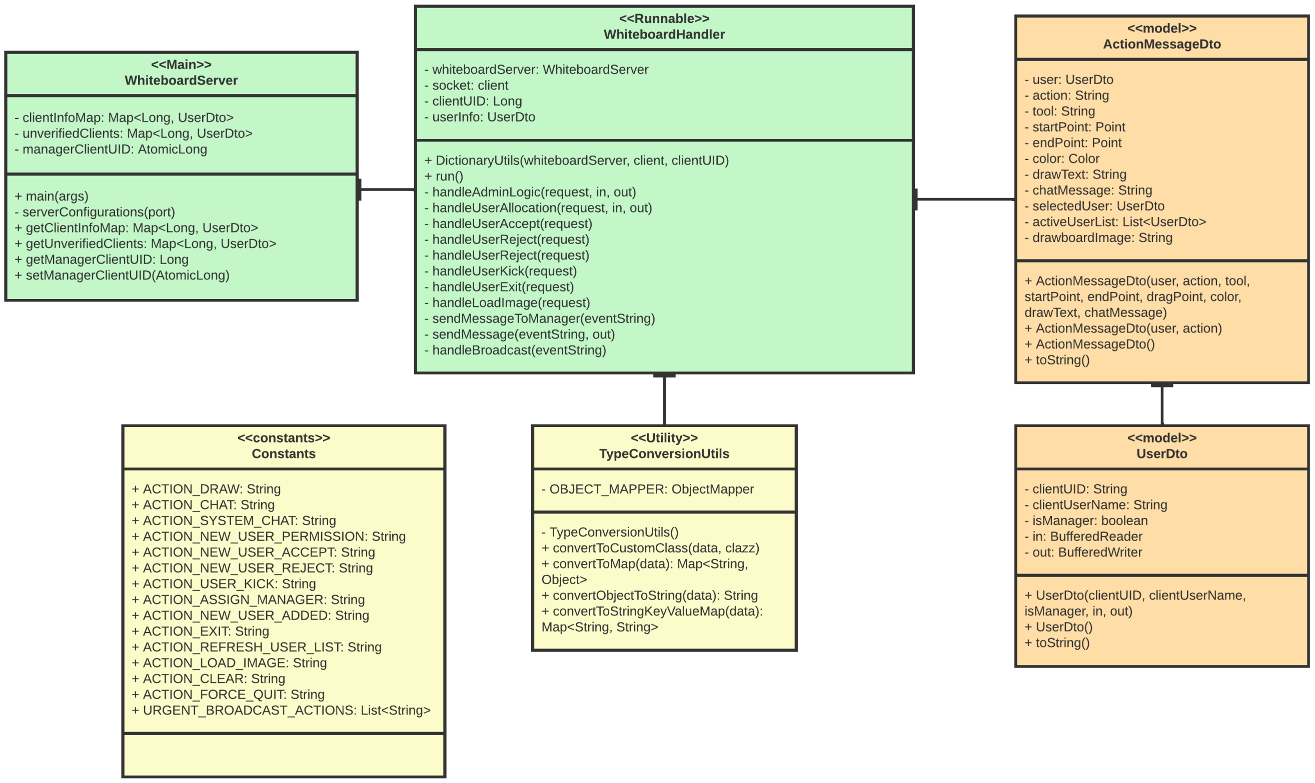

<<Main>>
WhiteboardServer
- clientInfoMap: Map<Long, UserDto>
- unverifiedClients: Map<Long, UserDto>
- managerClientUID: AtomicLong
+ main(args)
- serverConfigurations(port)
+ getClientInfoMap: Map<Long, UserDto>
+ getUnverifiedClients: Map<Long, UserDto>
+ getManagerClientUID: Long
+ setManagerClientUID(AtomicLong)
<<Runnable>>
WhiteboardHandler
- whiteboardServer: WhiteboardServer
- socket: client
- clientUID: Long
- userInfo: UserDto
+ DictionaryUtils(whiteboardServer, client, clientUID)
+ run()
- handleAdminLogic(request, in, out)
- handleUserAllocation(request, in, out)
- handleUserAccept(request)
- handleUserReject(request)
- handleUserReject(request)
- handleUserKick(request)
- handleUserExit(request)
- handleLoadImage(request)
- sendMessageToManager(eventString)
- sendMessage(eventString, out)
- handleBroadcast(eventString)
<<model>>
ActionMessageDto
- user: UserDto
- action: String
- tool: String
- startPoint: Point
- endPoint: Point
- color: Color
- drawText: String
- chatMessage: String
- selectedUser: UserDto
- activeUserList: List<UserDto>
- drawboardImage: String
+ ActionMessageDto(user, action, tool, startPoint, endPoint, dragPoint, color, drawText, chatMessage)
+ ActionMessageDto(user, action)
+ ActionMessageDto()
+ toString()
<<constants>>
Constants
+ ACTION_DRAW: String
+ ACTION_CHAT: String
+ ACTION_SYSTEM_CHAT: String
+ ACTION_NEW_USER_PERMISSION: String
+ ACTION_NEW_USER_ACCEPT: String
+ ACTION_NEW_USER_REJECT: String
+ ACTION_USER_KICK: String
+ ACTION_ASSIGN_MANAGER: String
+ ACTION_NEW_USER_ADDED: String
+ ACTION_EXIT: String
+ ACTION_REFRESH_USER_LIST: String
+ ACTION_LOAD_IMAGE: String
+ ACTION_CLEAR: String
+ ACTION_FORCE_QUIT: String
+ URGENT_BROADCAST_ACTIONS: List<String>
<<Utility>>
TypeConversionUtils
- OBJECT_MAPPER: ObjectMapper
- TypeConversionUtils()
+ convertToCustomClass(data, clazz)
+ convertToMap(data): Map<String, Object>
+ convertObjectToString(data): String
+ convertToStringKeyValueMap(data): Map<String, String>
<<model>>
UserDto
- clientUID: String
- clientUserName: String
- isManager: boolean
- in: BufferedReader
- out: BufferedWriter
+ UserDto(clientUID, clientUserName, isManager, in, out)
+ UserDto()
+ toString()

Figure 1: Whiteboard Server Architecture

4 Client Architecture

4.1 Whiteboard Client

The whiteboard client is initialized by running the ***WhiteboardClient.java*** file. It connects to the server host address and port defined by the user at the start of the application. Once connected to the server, it opens up an input and output stream with the server. It then assigns different threads for receiving and sending events through the stream to the server. Additionally, this class also keeps track of the user information and a concurrent queue for adding events to be sent to the server. The client handles all types of exception related to incorrect startup and wrong usernames, and displays them to the user for error reporting.

4.2 Listeners and Dispatchers

The whiteboard client keeps two threads running indefinitely for listening and dispatching events from the server. The ***EventDispatcher.java*** file implements the *runnable* interface and is used to dispatch events to the server. It runs in an infinite loop and keeps polling the action queue for any events added by the client for dispatching. Once it finds an event in the queue, it converts the event to a string and sends it to the server using the buffered writer through the socket. The ***EventListener.java*** file implements the *runnable* interface and is used to listen to the events coming from the server using the buffered reader object. It runs in an infinite loop as well while reading the input stream connected to the server for the events. Once it receives an event from the server, it converts the message to relevant DTO and processes them by performing drawings, adding messages to the chat-box, user removal, and loading images. We use separate threads to handle receiving and listening so as to let multiple users work simultaneously on the whiteboard and not hamper the user experience.

4.3 Whiteboard Client UI

The whiteboard client user interface is initialized by the ***WhiteBoardUI.java*** file. The class itself extends *JFrame* for easier integration with other components. On startup, it displays a user login dialog which takes the input of the display name from the user. The frame contains seven *JPanels*, which are used for different functionalities. The ***HeaderPanel.java*** file is used to display the title of the user interface, which appends the user name once the user has been accepted. The ***FileFunctionPanel.java*** file is used to display the file function buttons which are only accessible by the manager, it also displays the type of user using the whiteboard i.e manager or guest. The ***ToolPanel.java*** file is used to display buttons for tools that can be used for freehand drawing or drawing shapes onto the whiteboard using different colors, it also displays the current editor of the whiteboard. The ***UserPanel.java*** file is used to display the list of active clients connected to the shared whiteboard, it also provides the remove button functionality to the manager to kick clients from the whiteboard. The ***DrawArea.java*** file is used for providing a blank canvas to the clients for drawing purposes. The ***ChatBoxPanel.java*** file is used to display the chat history and provide a text input field for users to type text and send using the send button. The ***CoordinateBar.java*** file is used to display the coordinates of the mouse pointer on the drawing area, it also has an exit button for users to exit the whiteboard gracefully. Files for each component are kept separate so that it is easier to add new components, debug issues, and refactor code in the future.

4.4 Whiteboard Client Utilities

The whiteboard client application uses utility classes for different kinds of operations such as processing the events received by the server, holding constants, and encryption and decryption of messages. For processing the events received by the server and converting them into relevant DTOs, the ***TypeConversionUtils.java*** file is used, it is also used for converting the DTOs back to strings to send them over the network. The ***AESUtils.java*** file is used to encrypt and decrypt chat messages sent over the network using the AES[2] encryption algorithm with CBC[3] variation. ***Constants.java*** file is used to hold constants that are used repeatedly in the code to reduce code duplication and keep them in a single place for further refactoring.

[2]Advanced Encryption Standard
[3]Cipher Block Chaining

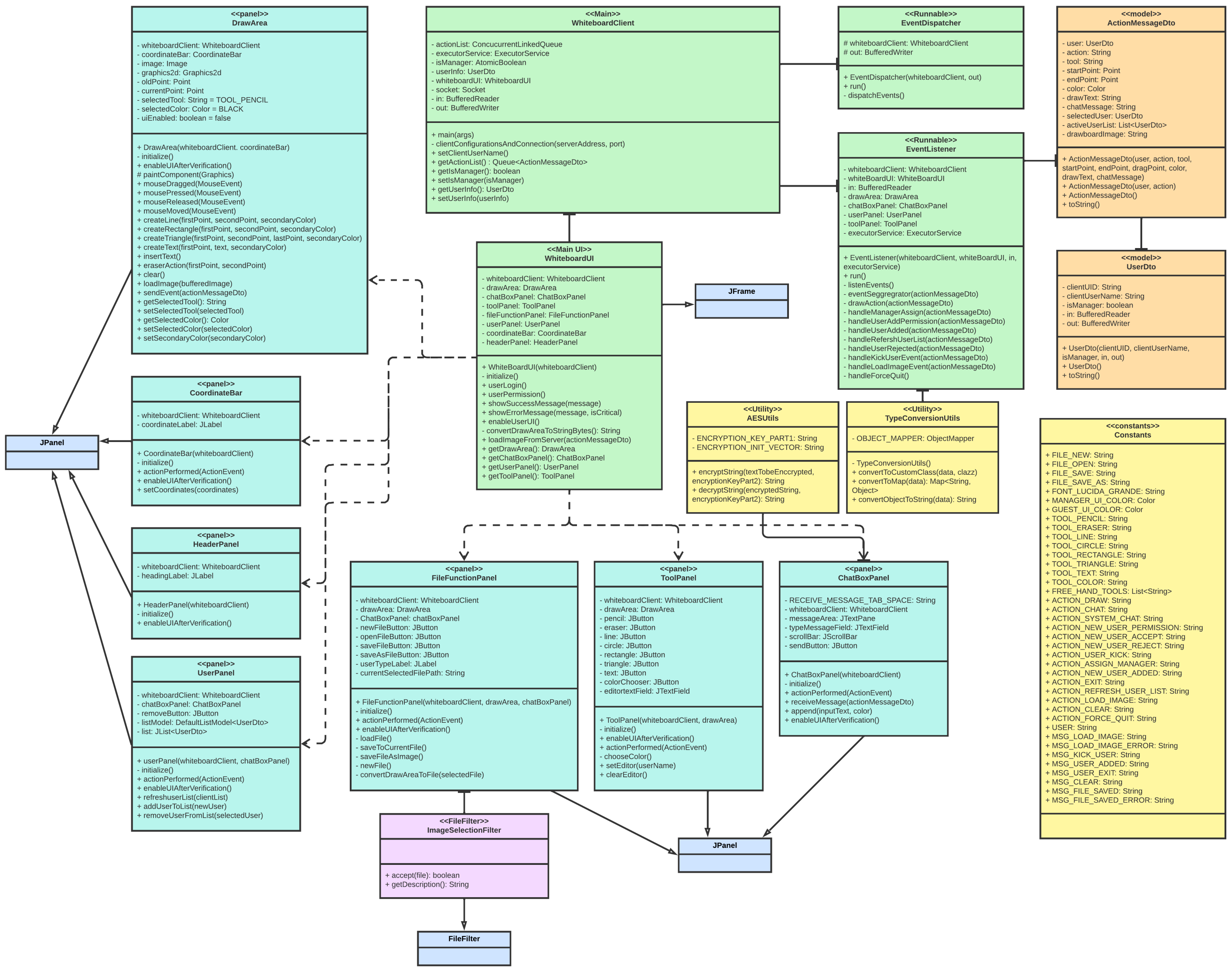


Figure 2: Whiteboard Client Architecture

5 Application Flow

Firstly, a whiteboard server application is initiated which opens up a server socket on the provided port. The server keeps the socket open and waits for client connections. Once the whiteboard client is up and running, whiteboard clients are initiated. As soon as the server receives an incoming client connection request, it assigns thread to a particular client for processing the client requests. Once the client is initiated, it opens a dialog for the user to enter the username. As soon as the user enters the username, a join request is sent to the server and the client is displayed a disabled UI of the shared whiteboard. Once the server receives the user permission request, it assigns the first user joining in as the manager, and the following user's request is sent to the manager for approval and the user information is kept on the unverified map so that the client does not receive any broadcast events. If the manager accepts the join request, the new user's UI is enabled and it receives the latest image of the whiteboard for synchronization purposes. The other active clients also receive the user added event and add the user to the active client list. All the drawing and chatting events are sent from client to server, in turn, the server broadcasts all the events to active clients except the user who sent them. The manager can load an image on the whiteboard from the local computer, which in turn is sent over the network for other clients to load the same image. Once a user has been removed from the whiteboard or exits the whiteboard, the client is notified and it sends an exit event to the server for graceful closure of the application, which closes the sockets and returns the assigned thread to the thread pool for future clients to connect. Lastly, if the manager exits the application, it sends an exit message to the server and the server, in turn, sends the force quit event to all clients since the manager has exited the application.

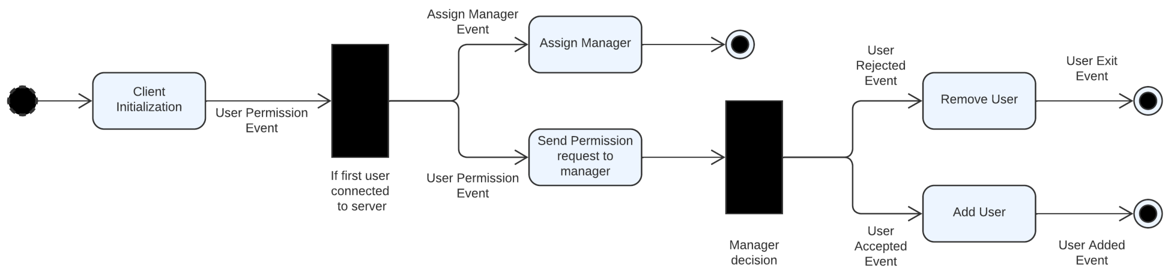


Figure 3: User Allocation Flow

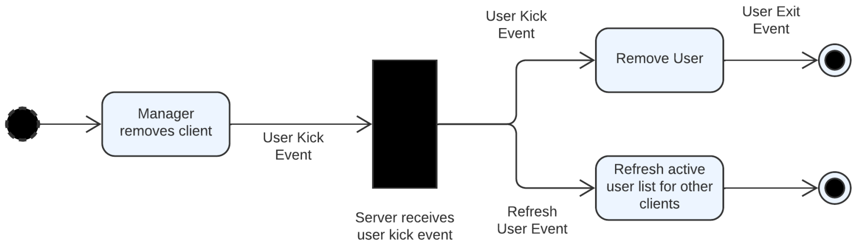


Figure 4: User Removal Flow

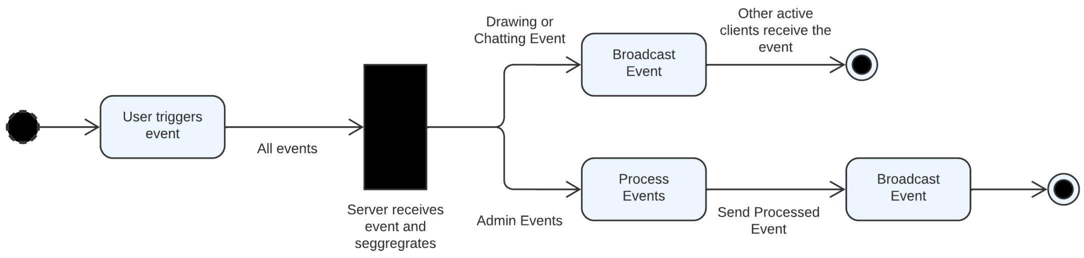


Figure 5: Event Broadcast Flow

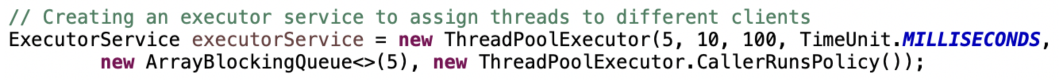
6 Critical Analysis of Components

6.1 TCP Connection

The whiteboard client-server architecture uses TCP[4] for connection between the server and multiple clients. This protocol was chosen because it requires a connection to transmit data which guarantees the delivery of data from one connected application to other. Since each request sent by a whiteboard client is important to acknowledge and respond to, guaranteed delivery is a huge advantage while using TCP. Once data is sent from one node, it also guarantees the sequencing of the data which cuts down on a lot of processing on both the server and the client-side. TCP also performs extensive error checking and acknowledgment of data which puts TCP over UDP[5] in terms of reliability. Lastly, Java has great support for TCP and it makes it easier to code and maintain for a small-scale application like the shared whiteboard.

6.2 Thread Pool Worker

The shared whiteboard server uses a thread pool worker to assign threads to clients that connect to the whiteboard server for maintaining separate connections and handling events triggered by them parallelly. The whiteboard client also used a thread pool to assign different threads for listening and dispatching events and executing other I/O blocking tasks. The thread pool architecture was chosen for this application because if we add clients and receive a large number of requests we may end up creating threads uncontrollably, which will ultimately lead to depletion of resources and performance. The clients may generate or receive a huge number of events at any particular time which might slow down the application. Thus, using this architecture helps save resources and keeps the application running with some predefined limits. It also increases the performance of the system scheduler that decides which thread gets access to resources next. In the application, we make use of the *ExecutorService* interface for creating a thread pool. To fine-tune the thread pool implementation we use the *ThreadPoolExecutor*, which gives us a handle on the parameters like *corePoolSize*, *maximumPoolSize*, and *keepAliveTime*.



```
// Creating an executor service to assign threads to different clients
ExecutorService executorService = new ThreadPoolExecutor(5, 10, 100, TimeUnit.MILLISECONDS,
        new ArrayBlockingQueue<>(5), new ThreadPoolExecutor.CallerRunsPolicy());
```

Figure 6: Executor Service Initialization

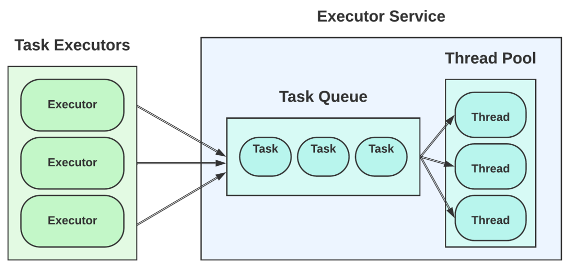
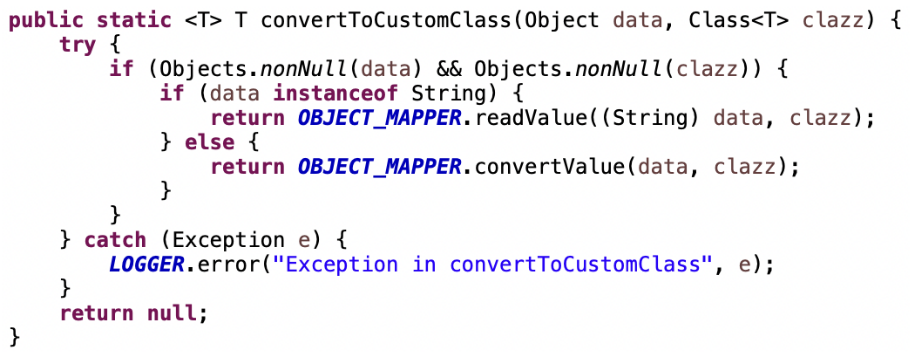


Figure 7: Executor Service Architecture

[4]Transmission Control Protocol
[5]User Datagram Protocol

6.3 Message Exchange (JSON & DTO)

For exchanging requests and responses over the TCP network, the application makes use of JSON[6] format which is used for serializing and transmitting structured data over the network. This format of message exchange was chosen as it creates a structured format that is also human-readable. It is also easy to read and write this format to a java class which is known as DTO[7]. The JSON string received by the client and server is deserialized to the ***ActionMessageDto.java*** file and ***UserDto.java*** file by using the Jackson Object Mapper, which is a lightweight JSON library for Java.

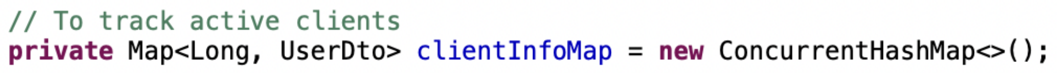


```java
public static <T> T convertToCustomClass(Object data, Class<T> clazz) {
    try {
        if (Objects.nonNull(data) && Objects.nonNull(clazz)) {
            if (data instanceof String) {
                return OBJECT_MAPPER.readValue((String) data, clazz);
            } else {
                return OBJECT_MAPPER.convertValue(data, clazz);
            }
        }
    } catch (Exception e) {
        LOGGER.error("Exception in convertToCustomClass", e);
    }
    return null;
}
```

Figure 8: String to DTO Transformation

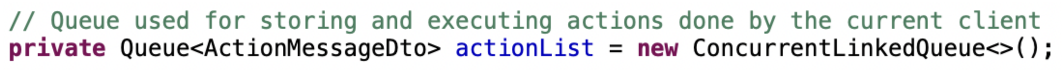
6.4 Track Active Clients & Events Triggered

The whiteboard server keeps a track of the active clients by storing the client's information in a concurrent map, to broadcast the events received by the server to other clients. It also stores information about the unverified clients in a concurrent map to inform the unverified clients about the acceptance or rejection from the manager. We use Java's *ConcurrentHashMap* which maintains concurrency in a multi-threaded environment. The whiteboard client keeps a track of all the events triggered by the client by storing them in a concurrent queue. It then fetches the events from the queue and dispatches them to the server. We use Java's *ConcurrentLinkedQueue* for achieving concurrency since multiple threads might be adding or accessing the queue at the same time.



```java
// To track active clients
private Map<Long, UserDto> clientInfoMap = new ConcurrentHashMap<>();
```

Figure 9: Java Concurrent Hash Map



```java
// Queue used for storing and executing actions done by the current client
private Queue<ActionMessageDto> actionList = new ConcurrentLinkedQueue<>();
```

Figure 10: Java Concurrent Linked Queue

[6] Javascript Object Notation

[7] Data Transfer Object

6.5 Security

The whiteboard clients encrypts the chat messages sent over the network and then decrypts the messages once received from other clients. The symmetric-key block cipher plays an important role in data encryption. It means that the same key is used for both encryption and decryption. AES[8] is a widely used symmetric-key encryption algorithm, which is also used in this application. The AES algorithm is an iterative, symmetric-key block cipher that supports cryptographic keys (secret keys) of 128, 192, and 256 bits to encrypt and decrypt data in blocks of 128 bits. We use the CBC[9] variation of AES, which uses an IV[10] to augment the encryption. First, CBC uses the plain-text block XOR with the IV. Then it encrypts the result to the cipher-text block. In the next block, it uses the encryption result to XOR with the plain-text block until the last block. This way we can secure sensitive data being sent across the network.

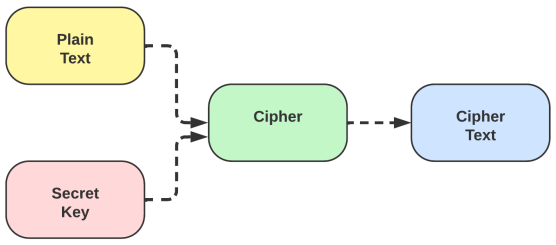


Figure 11: High Level AES Algorithm

6.6 Logging Framework

The whiteboard application logs all the important information in the console in a structured manner. The exceptions occurred during execution are handled and displayed with the time, thread, class and the exception message itself. The important events received or sent by the client are also logged to check correct working of the system. We use the *Logback framework* which offers faster implementation and provides more configuration and flexibility.

6.7 Maven Project Management

Both the whiteboard server and client use a lot of external *JARs* for various functionalities defined above. We use *Maven* as our project management tool which allows a project to centralize the dependencies of external *JARs* and use them freely in our application. We also use the *Maven Shade Plugin* that helps package the application into an executable *JAR* which contains all the dependencies so that it can be executed on any machine with a *JVM*.

[8]Advanced Encryption Standard
[9]Cipher Block Chaining
[10]Initialization Vector

7 Further Improvements

The application has a lot of basic drawing functionalities which can be improved by adding the rubber-band effect, that allows a user to see the temporary image of the shape being created. We can also provide the functionality of selection particular shapes and moving and resizing them. In the whiteboard client instead of running two threads indefinitely we can make use of different messaging frameworks like *Apache Kafka* - a pub-sub[11] messaging system, which can allow us to make application more streamlined and use less resources. As of now our server only detects disconnections through graceful shutdowns of the client, we can implement a knock-knock server that keeps checking the client connection state and work accordingly. The whiteboard server can be improved by implementing SSL[12] sockets for enhancing security of the data transferred over the network. We can also provide server the functionality to handle different sessions of whiteboard with different managers.

8 Conclusion

In conclusion, we created a multi threaded shared whiteboard application with a client-server architecture that uses TCP connection. It can handle different types of events like drawing and chatting, concurrently which allows user the experience of editing the same whiteboard with multiple clients. We use thread pool worker for making efficient use of resources. We use concurrent maps and queues for storing data that can be accessed by multiple threads to avoid deadlocks. We make use of JSON for structured storage of data and message exchange. The whole application handles different kinds of errors and reports it to the user with appropriate messages.

9 User Interface Components

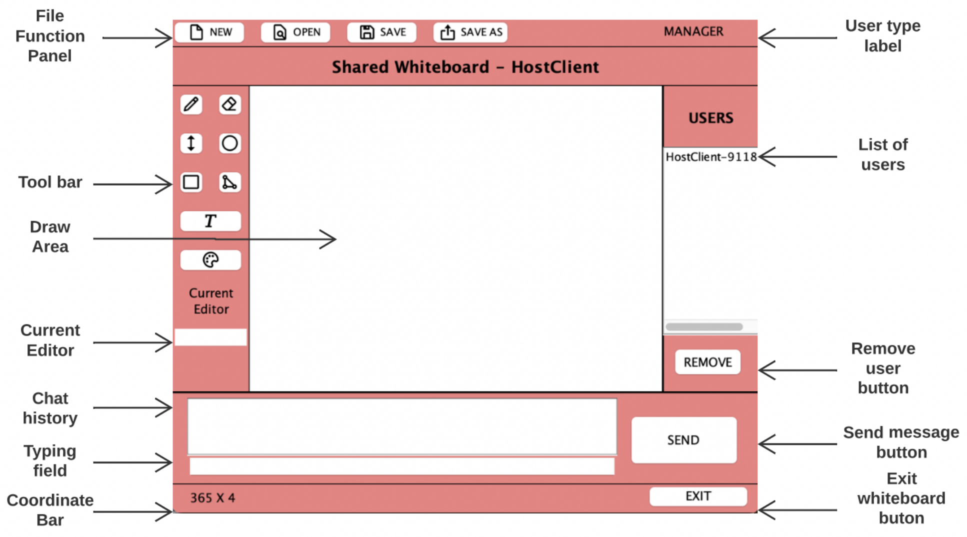


Figure 12: Whiteboard Client Interface

[11]Publisher-Subscriber
[12]Secured Socket Layer