



UNIVERSITÀ DI PISA

Computer Engineering

Distributed Systems and Middleware Technologies

Project Documentation

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1 — Project Specifications

AuctionHandler is a distributed web-app in which users can sell their goods by creating Online Auctions. Registered users have the possibility to join an ongoing auction in order to buy a good in case they beat the concurrence by setting an higher offer on a given limited time.

1.1 Use Cases

An *Unregistered User* can:

- Register to the service

A *Unlogged User* can:

- Login to the service

A *Logged User* can:

- View the list of ongoing Auctions
- Create a new Auction
- Join an ongoing Auction
- Logout
- After Joining an Auction:
 - Make an offer
 - View list of participants
 - View past offer history
 - View the remaining time
 - Wait until the end of the Auction and then exit
 - View Auction result

The *System* must:

- Remember registered users
- Remember ongoing auctions
- Remember auction participants
- Choose in a unique way the auction winner
- Remember offers history
- Synchronize the remaining time, the auction participants, the offer history for an auction for each user
- Synchronize the list of ongoing auctions for each user

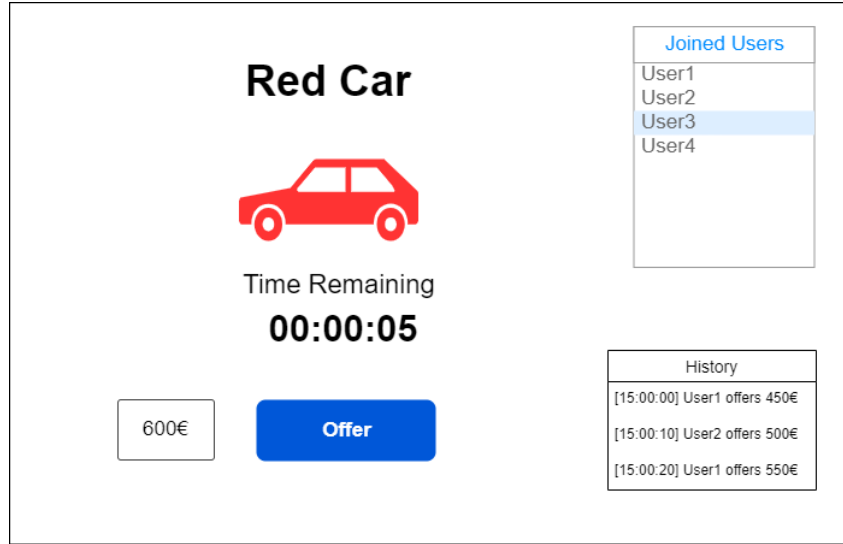


Figure 1: Mock-up of the main interface of the auction

1.2 Synchronization and Communication Issues

On the application we have the following synchronization and communication issues:

- Client nodes need to be synchronized with the same remaining time of the auction, the same offer history for a given auction, the same list of joined users on a given auction and the same list of available ongoing auctions.
- In case a client makes a valid offer, the server will be in charge of communicating to other clients nodes the information regarding the made offer.
- In case a client creates a new auction, the server will be in charge of communicating to other clients the information regarding the newly created auction.

2 — System Architecture

A graphical representation of the system architecture can be seen in figure 2.

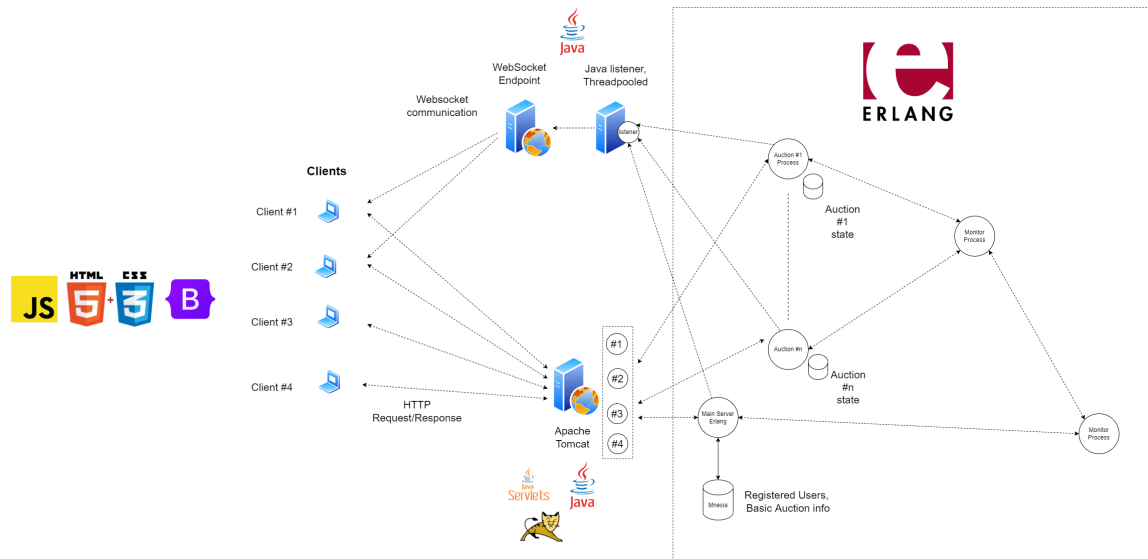


Figure 2: System Architecture graphical representation

We can divide the overall system in two part:

- The server side part: developed in Erlang, it is in charge of handling the request coming from the users and it has to handle the auctions and to maintain the global view of an auctions consistent among the users.
- The client side part: developed in Java, using Servlets and JSP for handling HTTP requests, content generation and websocket endpoint, and in Javascript for what the handling of websocket messages. It is in charge of retrieving information from the server, create the GUI, update the GUI in order to let the user have a consistent view of the state of the auction and of the overall system.

The server-side part written in Erlang and the Java Listener are deployed in the container **172.18.0.7**, Apache Tomcat webserver which hosts the Web Application is deployed in the container **172.18.0.6**. Is possible to access those containers by using OpenVPN with the file *studenti.ovpn* that can be found in the main project repository: <https://github.com/gerti98/DistributedSystemsProject>

The Web-App can be accessed through the following link:
<http://172.18.0.6:8080/AuctionHandlerWebApp/LoginServlet>

2.1 Server Side

The Server side part is written in Erlang and contains the following components:

- The Main Server

- Auction Handler
- Auctions Monitor
- Supervisor
- MnesiaDB

2.1.1 Main Server

The main server is in charge of receiving requests from the client side and saving all the necessary information in the database.

Since robustness is required the main server is an OTP `gen_server`. The main server is actually composed by an endpoint and by the actual server. The endpoint is a sort of API used to make a call to the OTP `gen_server`:

1. The client sends a message to the endpoint
2. The endpoint receives the message, analyzes it and calls the function that uses the function call in order to make a request to the OTP `gen_server`
3. The OTP `gen_server` receives the request and calls the function `handle_call` that matches with the incoming message pattern.
4. The `handle_call` function will manage the request arrived from the client and sent back the required information (saving info in the database or spawning process if necessary)

The functionalities that the server exposes are:

- Register a new user

The user will be registered (i.e. added to the database) if and only if its username is not already present in the database.

- Login

The username and password are checked and if both are correct a positive reply is sent back

- Create Auction

A new auction is created (added to the database) if and only if another auction with the same name is not already present in the database. When the auction is created a new process (i.e. The Auction Handler) is spawned and this process is added to the processes that the Auctions Monitor has to monitor (for more detail about the monitoring see 2.1.3). From now on for all the information regarding that auction the client has to contact the auction handler at the pid present in the reply message.

- Retrieve Auction PID

Return back to the user the PID of the handler that manages the auction with the name passed to the server in the payload of the request. This is very useful for instance when the auction handler crashes and it is re-spawned. In that cases the PID changes and so the client has to know the new one.

- Retrieve Active Auctions
Return back the list of all the active auctions (They are saved in the database).
- Retrieve Passed Auctions
Return back the list of all the passed auctions (They are saved in the database).
- Update Win
Save the username of the auction's winner. This functionality is used by the auction handler in order to store in the persistent storage the name of the winner.
- Update PID
Change the PID of the auction handler associated to a particular auction. This is used by the auction monitor when an auction handler crashes and so it is re-spawned with a new PID.

2.1.2 Auction Handler

The auction handler's role is to manage an auction maintaining its state. Its functionalities are:

- Maintain the time that remains for the end of the auction.
Each seconds a clock message is sent by the auction handler to itself in order to emulate the passing time. When the remaining time is 0 (the information about the remaining time are kept into the handler state) then the auction handler has to decide the winner. After this decision the handler kills itself.
- Remember which users are online at any moment
Each time a new user enters the auction or leave it, we update the handler state and we notify the client through the Java Listener.
- Register the offers
When a new offer arrives the handler saves it into an ordered list¹ (the higher offers is at the beginning of the list) in its internal state. Notice that the offer is registered only if the offer amount is higher w.r.t. the minimal amount.
- Decide the winner
The winner is the one whose offer is in the first position in the list of the offers. If the list is empty then this means that no offers have been made and so there is no winner. When the winner is decided the client and the main server are notified.

2.1.3 Monitor And Supervisor

It is possible to see a graphical representation of the monitoring relationships among processes in figure 3. The monitoring is performed by **My Supervisor** and **Auctions Monitor**.

¹The list is composed by tuples e.g. {"UserA",10}

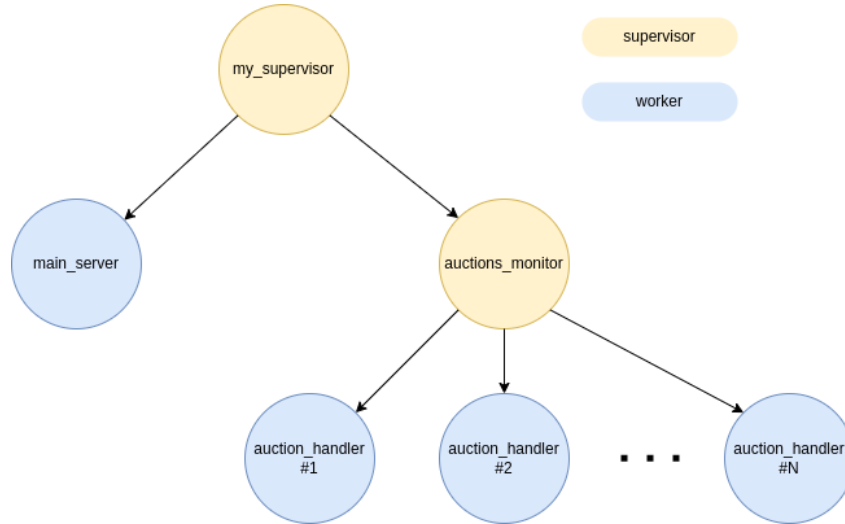


Figure 3: Graphical representation of how the monitoring is implemented. Notice that in the draw the arrow starts from the monitoring process and ends to the monitored process.

My supervisor is the main supervisor and due to its importance and the robustness required is developed using an OTP supervisor behaviour. The process that it monitors are `main_server` and the `auctions_monitor`, both of them are *permanent*. A monitored process is said to be permanent if it is always restarted when necessary. The restart strategy is *one_for_one* since with this strategy we are able to provide the service even if one between main server and auctions monitor crashes. One for one means that if one of the monitored process crashes then only the crashed one is restarted. In our scenario we can have two possibilities:

- Main Server crashes

If the main server crashes before the auction monitor we can just restart it and we have no side effect.

- Auctions Monitor crashes

If the auctions monitor crashes and it is restarted then all the auctions created before the crash are not monitored anymore. Anyway that auctions are still reachable by the user and, moreover, the situation is temporary and when the old auctions are terminated we have the standard situation in which all the auctions handler are monitored.

Thus as we can see with this strategy in both cases we are still able to provide the correct service.

The auctions monitor is a custom monitor which is in charge of restart an auction handler when it crashes. To do so it saves in its internal state all the necessary info, in this way when a process crashes abnormally, the auctions monitor restart it and it notifies the main server in order to update the pid with the pid of the new re-spawned auction handler.

Notice that when the auction handler is re-spawned the state of the auction is the initial one (the state we would have just after the creation of the auction).

Another thing to highlight is that if the auction handler terminates correctly the auctions monitor does nothing. In fact each auction handler kills itself when the auction ends.

2.1.4 MnesiaDB

The module MnesiaDB is the one in charge of managing the persistent storage. Mnesia has three options regarding the storage persistence (the following three definition are taken from the documentation²):

- *ram_copies*. A table can be replicated on a number of Erlang nodes. Property *ram_copies* specifies a list of Erlang nodes where RAM copies are kept. These copies can be dumped to disc at regular intervals. However, updates to these copies are not written to disc on a transaction basis.
- *disc_copies*. This property specifies a list of Erlang nodes where the table is kept in RAM and on disc. All updates of the table are performed in the actual table and are also logged to disc. If a table is of type *disc_copies* at a certain node, the entire table is resident in RAM memory and on disc. Each transaction performed on the table is appended to a LOG file and written into the RAM table.
- *disc_only_copies*. Some, or all, table replicas can be kept on disc only. These replicas are considerably slower than the RAM-based replicas.

The option chosen is *disc_copies* since makes the database resilient against crashes and allow us to restart the processes without issues. Moreover since the database is kept also on RAM we have also quicker operations (w.r.t. the case *disc_only_copies*).

In the database there are two tables:

- User

The attribute of this table are *name* and *password*. It is in charge of remember the users registered to the application.

- Auction

The attribute of this table are *name*, *duration*, *startingValue*, *imageURL*, *creator*, *pid*, *winner*. It is in charge of remember all the info regarding an auction. An important attribute is *winner*, this attribute is used to distinguish between passed auction and active auction: if the auction is active winner is equal to none, instead if the auction is finished, winner contains a string with the name of the winner or a particular string indicated that there is no winner (if the auctions has received no offers).

A particular feature of Mnesia db is the possibility to use *Atomic transactions*. An atomic transaction ensures that all the operations inside the transaction are performed in an atomic way. This feature is used for the user registration and for auction creation. In both cases we need to register the user or create the auction only if there is not an auction/user with the given username/auction_name. To ensure this we need a read on the database and then a possible write. If the two operations are not done in an atomic way (i.e. inside the same transaction) we may have the following situation:

²<https://www.erlang.org/doc/man/mnesia.html>

- Alice tries to register itself with the username "john-doe"
- READ (triggered by Alice): There are no user whose username is "john-doe" so I can perform the write
- Bob tries to register itself with the username "john-doe"
- READ (triggered by Bob): There are no user whose username is "john-doe" so I can perform the write
- WRITE (triggered by Alice): I write "john-doe" in the table *user*.
- WRITE (triggered by Bob): I write "john-doe" in the table *user*. This write will cause an inconsistency because we will have two users registered with the same name.

In practice we have a problem known as TOCTOU (Time Of Control Time Of Use) which consists in the fact that I can change the table after the check done during the read, thus when I perform the write the state of the table is changed because another operation has been performed between the read and the write.

The solution to this problem is the use of atomic transactions provided by Mnesia DB.

2.2 Client Side

The web application shown to the user is generated via Apache Tomcat web-server, the page update is managed asynchronously via web-sockets, the front-end part is done with Bootstrap (a pretty famous CSS & Javascript framework) and Javascript "vanilla".

2.3 Web-server with Apache Tomcat

In Apache Tomcat web-server HTTP requests arriving from the user are processed by Java Servlets:

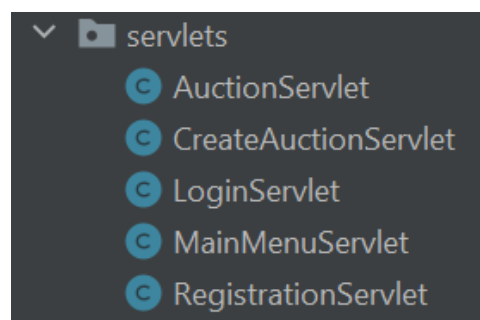


Figure 4

As shown in the above figure, there is one Java Servlet for each page of the web-application. From the generated page is possible to follow some hyperlinks to find other pages of the web-app.

The Webapp folder is organized in the following way:

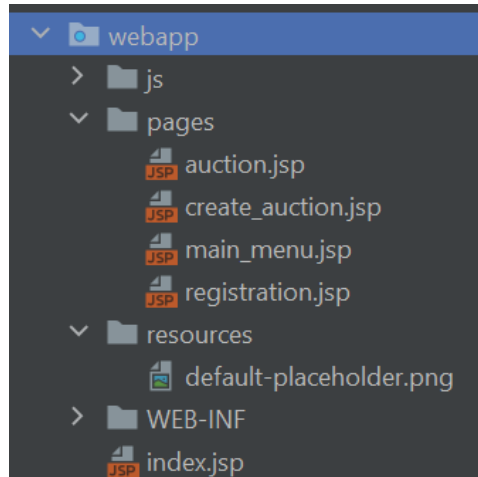


Figure 5

The actual HTML is generated via JSP technology, with some script-lets, for each page, in order to have a logic separation between the "View" part and the rest of the application. In example the *main_menu.jsp* scriptlet contains some logic to generate different cards by iterating the list of auction returned by the Erlang server.

In order to add some layers of security to the application a couple of Filters were added:

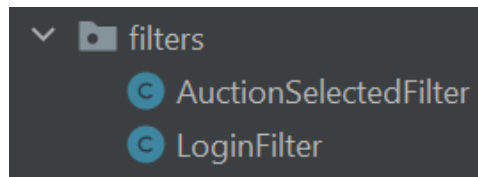


Figure 6

- **LoginFilter** is responsible for checking that requests to "protected" pages arrives from users that are already logged in (this can be assured by analyzing the session of the particular user, indexed by a cookie).
- **AuctionSelectedFilter** prevents a logged user to access an auction without having pressed the related button. This is done because at the same time multiple auctions can be running at the same time.

In order to update the "Model" part of our application some requests to the Server-Side part in Erlang needs to be done. This is dealt in the communication package:

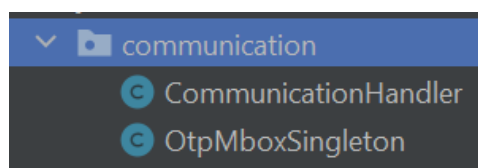


Figure 7

Jinterface library is used: for each client there is a different mailbox contained in one single "Erlang" node, which is unique since obtained from the session token of the client. Then a request/reply communication happens with the Erlang Main Server and if needed with the related Auction Handler, in case an auction page is requested. The communication will return back a result in order to communicate to the user if the request made has succeeded or not (i.e. a client registration may fail in case of a duplicate username).

2.4 Web-sockets

In order to update the application state without requesting periodically a web-page, Web-socket technology is used.

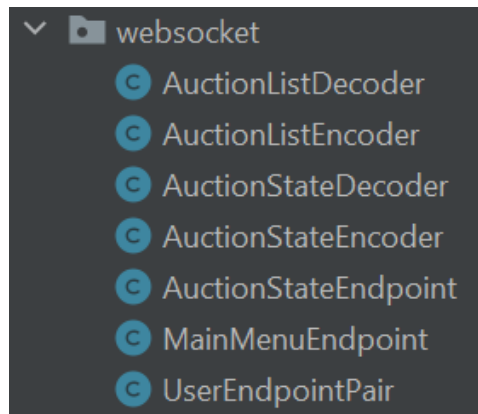


Figure 8

As we can see in the image above two different web-socket endpoint are used:

- **MainMenuEndpoint:** responsible for updating the state of the main menu w.r.t. the list of active and inactive auctions. Clients connected to this endpoint are registered through the usage of a Java static *CopyOnWriteArraySet* for dealing with concurrent changes of the connected client list.
- **AuctionEndpoint:** responsible for updating the state of the auction w.r.t. the list of joined users, the list of valid bids, the auction time, and the winner election. Clients connected to this endpoint are registered through the usage of a Java static *ConcurrentMap*<String, Set<UserEndpointPair>> data structure. With the latter, for each auction name is associated a list of client endpoints. This organization is made in order to correctly send auction messages only to clients that have joined a particular auction, with a publish/subscribe fashion.

2.5 Java Listener

There's one actor missing in the whole picture: the Java Listener. The web-socket state update happens with the following sequence of steps:

1. A client requests a change to the state of the model (i.e. creates an auction)
2. Apache Tomcat intercepts the requests and start the communication with the related Erlang server-side which actually stores the application state

3. The Erlang server-side sends in general **two messages for each requests**: one is for the servlet itself which acts as an ACK to the request made by the client, one is sent to the **java listener** for triggering the state change to other clients connected (without need of a page refresh)
4. Java listener broadcast the state change to all interested users via web-socket

The advantages of using this approach are the following:

- Since messages are sent by the erlang server-side (which actually is the source of truth of the web-application state), the state returned is consistent.
- Thanks to web-sockets, there's no need to periodically send request to Apache Tomcat. **Page updates happens only when there is a state change**, avoiding a considerable amount of computations and HTTP requests to be handled.
- Some events are triggered by erlang side itself and not by the client (i.e. auction ending and winner election), so this approach will update the web-application state correctly by simply avoiding to send one message to Apache Tomcat

The **cost** of this approach is the implementation of the Java Listener.

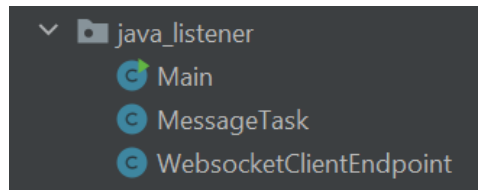


Figure 9

The Java Listener is implemented with a listener Jinterface node for getting requests from Erlang server-side. For handling multiple requests in parallel, threads are used: in particular, for avoiding the overhead due to the creation and termination of threads, **thread-pooling** is used via ExecutorService instance that implements a fixed thread pool. The task (called MessageTask) computed by each thread is related with sending a message (with the state information) to the correct web-socket endpoint.

2.6 User Interface

In order to ease the UI developing a framework like **Bootstrap** has been used, in order to create a responsive web-application in a simple way, with a set of ready-to-be-used css classes, without the need of reinventing the wheel by defining our set of css classes for getting the same result.

A couple of javascript scripts are then defined:

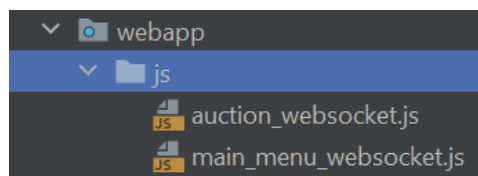


Figure 10

- **main_menu_websocket**: Responsible for connecting with the main menu websocket endpoint and to update the DOM of the HTML page when a message arrives.
- **auction_websocket**: Responsible for connecting the client to the auction websocket endpoint, to update the DOM of the HTML page when a message arrives and to update locally the timer.

For what concern form validation, **browser-default validation** was adopted (i.e. some fields are required to be added, some fields, like the auction duration, must contain a number).

3 — Synchronization And Communication Issues Resolution

As we have seen in section 1.2 the main issues regarding the synchronization and communication are:

- Maintain a consistent auction state (remaining time, users online, offers made) among the clients
- Maintain the list of auctions updated among all the users of the application
- Notify a client if something changes (new auction is created, a new offer is made, a new user joins the auction and so on)

These problems are solved using Erlang and Websocket. The server is made entirely in Erlang, thus all the problems regarding the concurrency are handled by the language. Apart from this all the remaining communication and synchronization issues are solved because:

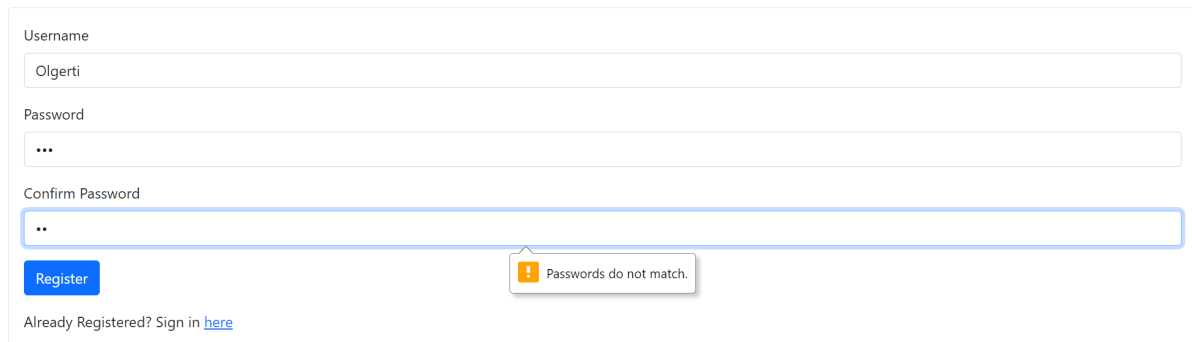
- Erlang maintains the remaining time (this is done by the auction handler) and all the important information, either regarding a single auction (auction handler) and the overall system state (main server and mnesia db).
- Websockets update all the registered clients with the newest information provided by the Erlang part of the application.

4 — User Manual

4.1 Registration and Login

An unregistered **User** can have access to the service only via prior Registration.

Auction Handler - Register Page



The screenshot shows the 'Auction Handler - Register Page'. It features three input fields: 'Username' (containing 'Olgerti'), 'Password' (containing three dots), and 'Confirm Password' (containing two dots). The 'Password' and 'Confirm Password' fields are highlighted with a blue border. Below the 'Confirm Password' field, a blue 'Register' button is visible. A small orange pop-up message with a warning icon and the text 'Passwords do not match.' is positioned over the 'Confirm Password' field. At the bottom left, there is a link: 'Already Registered? Sign in [here](#)'.

Figure 11: Registration Page

The registration page only involves the insertion of *username* and *password* fields. If the two passwords do not match a pop-up will be show to the **User**, as shown in the above figure.

After a successful registration, the **User** needs to login to the service, this can be done via a dedicated page to do so as shown in the figure below.

Auction Handler - Login Page



The screenshot shows the 'Auction Handler - Login Page'. It features two input fields: 'Username' (containing 'Olgerti') and 'Password' (containing six dots). Below the 'Password' field, a blue 'Login' button is visible. At the bottom left, there is a link: 'Not Registered? Sign up [here](#)'.

Figure 12

4.2 Main Menu and Auction Creation

A logged **User** has the possibility to see an overview of the ongoing auctions and the results of past auctions (in terms of who was the winner). For the latter if no winner was elected (i.e. due to lack of bids), the winner will be called *NoWinner*.

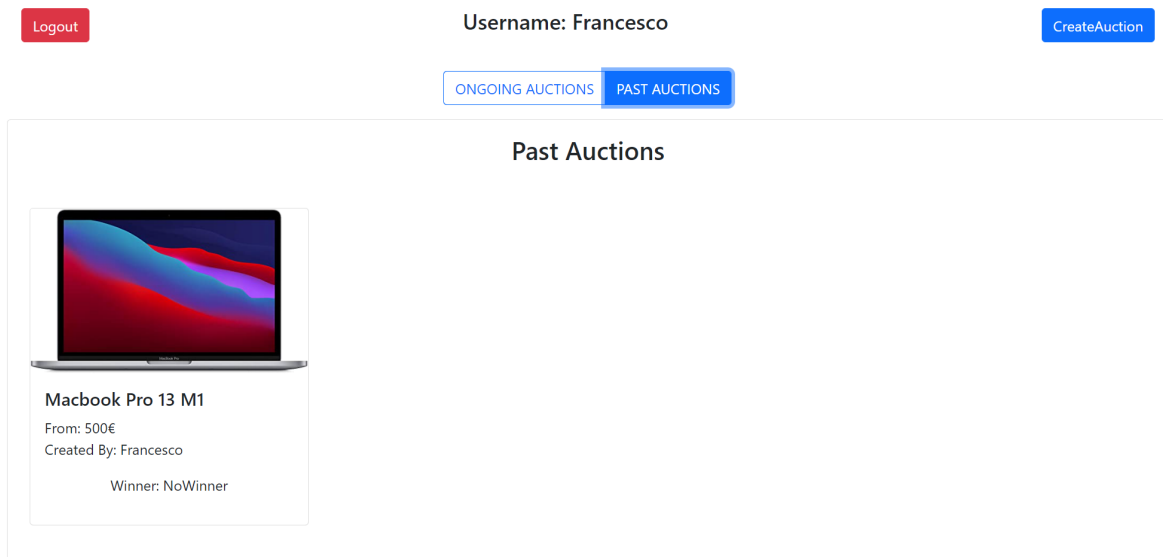


Figure 13: Past Auctions Tab

A **User** can also participate to an ongoing auction by pressing the related button of the ongoing auctions tab.

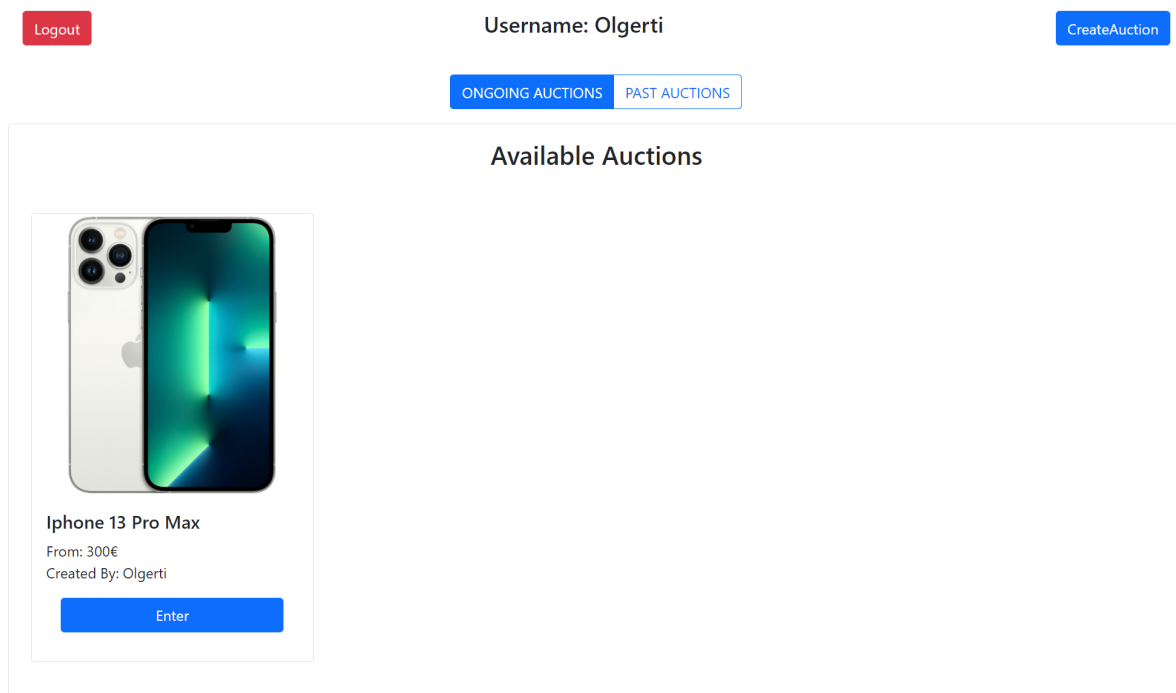


Figure 14: Active Auctions Tab

A **User** has also the possibility to create his own auction by pressing the *CreateAuction* button in the Main Menu. Another form will be shown as can be seen in the figure below.

Back

Create Auction

Good Name

Enter Good Name

Auction Duration

Enter the Auction duration in seconds

s

Start Value

€ Enter starting value

.00

Image URL

Enter URL of symbolic image

Create Auction

Figure 15: Create Auction Page

The **User** needs to add information about the *auction duration*, the *minimum bid* for the auction, the *good name* to sell (which must be unique) and an *image URL*. If the URL is invalid a default placeholder will be shown.

A logged **User** can perform logout by pressing the *Logout* button in the Main Menu.


4.3 Auction and Winner Election

When an auction is created or when a **User** joins an ongoing auction, the following page will be shown:

Back

Auction by: Olgerti

Iphone 13 Pro Max



Remaining Time: 00:29:26

€ Enter your bid

.00

BID

Joined Users

Olgerti

Francesco

Tommaso

Auction History

Francesco bids 900€

Tommaso bids 850€

Francesco bids 700€

Tommaso bids 600€

Francesco bids 500€

Figure 16

On the upper-right corner is shown the list of joined users. On the bottom-right corner the current list of valid bids that were made. A **User** can send a bid for the good if and only if it is not the creator of the auction and the bid value is higher than the last accepted bid (the first one shown in the Auction History table). If no bid are present then the bid value must be higher than the *minimum bid* inserted at auction creation. A **User** can decide to exit from the auction by pressing the *Back* button. At the end of the auction, each connected user will see the auction result by means of a pop-up, as shown in the figure below.

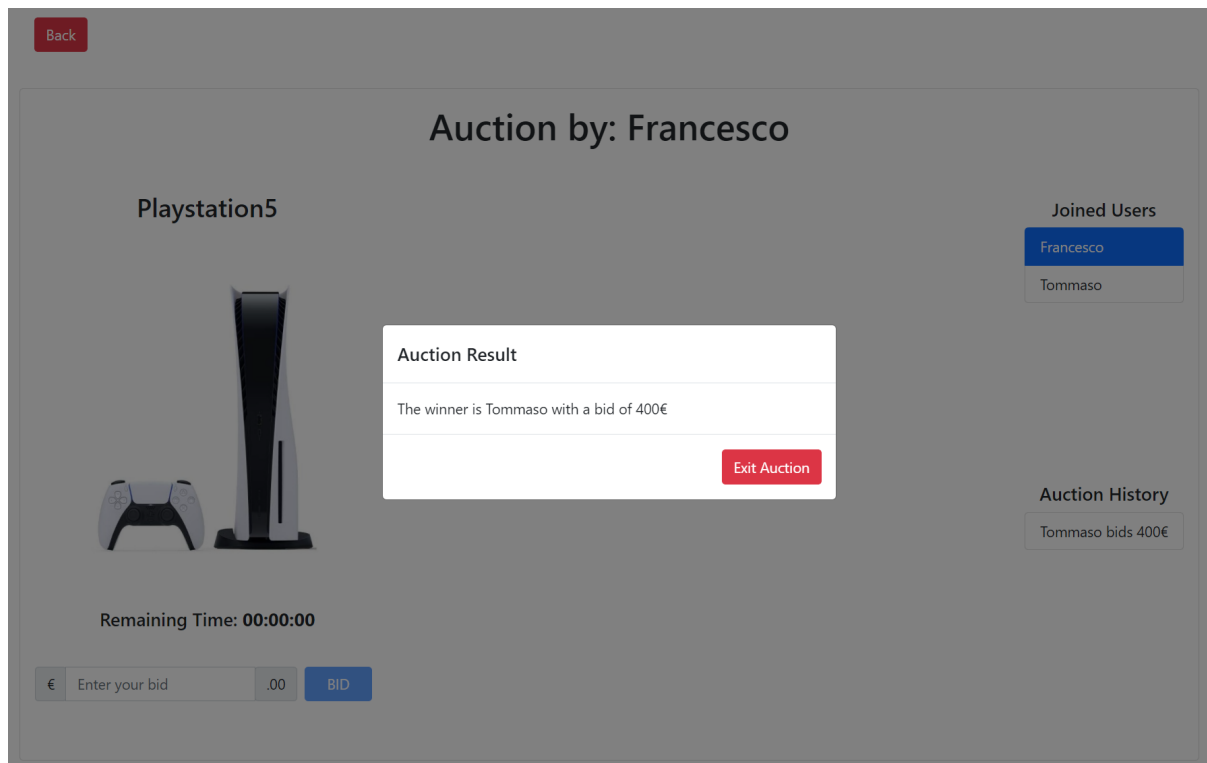


Figure 17: Auction Results