Politecnico di Milano
School of Industrial and Information Engineering

Software Engineering 2 Project

e-Mobility for All.

Requirement Analysis and Specification Document

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1 Introduction

1.1 Scope

eMall is a system meant to provide services for charging electric vehicles and managing charging stations. This is meant both for normal people (i.e. end users) and for CPO workers. The application domain concerns different types of world phenomena, shared phenomena and machine phenomena.
We can identify the followings world phenomena:

- [W1] User connects his electric vehicle to the charge socket.
- [W2] DSOs provide energy to their associated charging stations.
- [W3] Batteries, if available and enabled, store energy from DSOs and provide it to the charging station.
- [W4] Charging sockets are supplied directly by DSO through the network and/or by batteries of the charging station.

the following shared phenomena controlled by the world and observed by the machine:

- [S1] A user books a charge in a charging station.
- [S2] A user enables a charging column.
- [S3] CPOs decides to take energy from DSOs and/or from batteries, if available.

and the following shared phenomena controlled by the machine and observed by the world:

- [S4] Location, external and internal status of the charging station are visible.
- [S5] The system checks the booking ID and enables the charging operation.
- [S6] Vehicle charging is started.
- [S7] Vehicle charging is stopped and a notification is sent.
- [S8] The system elaborates the payment of the charging service.

1.2 Purpose

The system is characterized by the following goals:

- [G1] Users must know position, prices and special offers of charging stations.
- [G2] Users must be able to complete the whole process of charging for their electric vehicles.
- [G3] CPOs workers must be able to manage charging stations associated to their CPO.
- [G4] CPOs must be able to communicate with DSOs in order to provide energy furniture.

In the following table is shown which world and shared phenoma are involved for each goal.

	W1	W2	W3	W4	S1	S2	S3	S4	S5	S6	S7	S8
G1					X			X				
G2	X	X	X	X	X	X			X	X	X	X
G3		X	X	X			X	X				
G4		X					X					

Table 1.1: Correspondence between goals and world and shared phenoma

1.3 Definitions, acronyms and abbreviations

- *eMSP*: e-Mobility Service Provider.
- *CPO*: Charging Point Operator.
- *CPOW*: Charging Point Operator Worker.
- *CPMS*: Charge Point Management System.
- *DSO*: Distribution System Operator.

1.4 Revision history

- –/–/2022 Version 1.0.

1.5 Reference documents

- Assignment Document "Assignment RDD AY 2022-2023_v3.pdf".

1.6 Document structure (TO DO)

The document consists of 4 chapters:

Chapter 1: In this chapter the main problem is presented listing all the goals and the world and shared phenomena that the application observes and/or controls, which helps to better comprehend the domain of the application. It also provides some base information in order to make

more understandable the reading of the document.

Chapter 2: In this chapter the application itself is taken into consideration, concerning its functions and the potential stakeholders that actually will use it. Considering users and the world in which they act, all the assumptions made on the domain are listed. A series of UML diagrams (Class and State diagrams) are then presented to help understanding how the application should work in terms of entities involved and functionalities.

Chapter 3: In this chapter the application behavior is described: at first some scenarios are identified and then some UML diagrams (sequence and use cases diagrams) are provided, with a detailed analysis of the use cases; at last by specifying requirements in terms of :

- functional requirements.
- non-functional requirements.
- interface requirements.

Chapter 4: In the last chapter a brief but concise and effective formal analysis of the problem is presented using alloys. Some requirements and domain assumptions are formally specified and their consistency is verified, with the help of the Alloy tool.

2 Overall Description

2.1 Product perspective

This section is dedicated to the identification of the most important scenarios and to a first description of the whole system through class and state diagrams. Both the two different types of users and subsystems are considered.

2.1.1 Scenarios

For all scenarios described below we assume that the system provides a mobile application for end users and a web interface for CPOWs.

Unregistered end-user

A possible end-user has just bought his brand new Tesla Model X and has seen some interesting ads about the new application eMall, which will allow him to know where to charge his vehicle and manage the whole process. He decides to download the app and sign-up, filling in all the requested fields and starting using the app. He decides also to insert a picture of his driving license and to register his car inserting dates about the model and the plate. After that, he will include also all information about his debit card so, when he will decide to book a recharge everything will be ready.

Unregistered CPOW

A new CPOW has just been hired and on his first day of work, he needs to register to the eMall web service in order to manage the CPMS of the CPO he is working for. During the sign-up process, he has to insert, in addition to all requested fields, also a special code provided by his employer to register him as a CPOW.

End-user wants to book a charge

An end-user decides to open eMall app in order to see if there are news offers in the charging stations of his city and discovers that the one of the shopping mall has a discount of 25%. Tomorrow he will finish working at 6:30 pm and he needs to buy also a pair of shoes. So he decides to take advantage also of the special offer and clicks on the book button of the charging station on the map, selects his car and a payment method, and books a fast charging socket between 7 pm and 8 pm tomorrow.

End-user charges his vehicle

An end user arrives at the charging station where he has booked a medium-speed charging socket, presses the unlock button from the app, connects the socket to his car, and starts the charging process. Now he goes to get his hair cut and while he was looking at his new hairstyle in front of the mirror he receives a notification from eMall app which says that the charging process is finished. So he comes back to the charging station, presses the disconnect button on the app, and disconnects the charging socket. At this point, he receives a notification from his bank which says that 20 euros have been charged to his debit card.

CPOW registers a newly opened charging station

A CPOW has just received the assignment to manage through the CPMS a new charging station that will be inaugurated today in the main square of the city, that can be accessed only by electric vehicles. Since all connections between the station and the systems have been already configured by technicians he only has to add it on his web interface. He presses the *configure new station* button and fills all requested fields taking special care about the unique physical id identifier of the station that will allow him to manage it from his CPMS. At this point, the charging station configuration is ended and the management can start to work properly.

CPOW temporarily disable batteries due to maintenance

This night 4 batteries of charging station 1046 have to be removed following the regular maintenance schedule and a CPOW that manages the CPMS related to that charging station has to do some operations before the end of his turn at 6 pm. First of all, he selects that specific charging station on his web interface clicks the battery management button, and selects the 4 interested batteries. At this point, he selects programmed disabling and sets the batteries off from 9 pm of that evening. Since the recharging station has 2 more batteries he sets up to take 25% of energy from batteries and 75% directly from DSO during the charging processes of that night. The day after when the CPOW starts his turn at 9 am he receives a notification that the maintenance has ended and batteries have been correctly reconnected. So he re-enables them and set the charging station to take again 100% of energy from batteries.

CPOW shows to his manager dates about a charging station

Yesterday a new charging station has been opened in the parking of the city shopping center and this morning the manager knocks on the door of the office of the CPOW who manage, trough the CMPS, that specific station, in order to see if there are already some users. The CPOW opens his web interface, selects charging station 1050, and clicks on show statistics. The charging station is composed of 6 charging sockets, 3 at fast-speed and 3 at medium-speed, and 10 batteries. Currently, 2 cars are charging: the first one is a Honda-e, connected to socket 1 (fast-speed charge), that has absorbed 19/35.5kwh of power and will take 12 minutes to complete the charging process. The second one is a Hyundai Kona Electric, which is connected to socket 4 (medium-speed charge), that has absorbed 10/64kwh of power and will take 55 minutes to complete the charging process. The CPOW and the manager see also that 12 other recharges have been booked from now to midnight, 7 on fast-speed sockets and 5 on medium-speed ones. Actually only one of the 10 batteries is at 53% of his charge and the remaining 9 are all full. The manager is pretty satisfied since it is only the second day since the station has opened and he can see encouraging results. So he invites the CPOW for a coffee break and they go to the coffee machine together.

CPOW manually decides where to get energy

An eMSP company made a deal with a DSO company and if they will purchase energy only from them for one month they will reduce the price making it the most convenient for the eMSP. So all CPOWs of the interested CPO have been instructed to proceed in this way. We took as an example one of them. This specific CPOW decides to have a look at the different offers from all available DSO and he notices that actually the one of the deal isn't the cheaper, so the system won't dynamically decide to acquire energy from that specific company. So, through the web interface of the CMPS, he switches off the auto-deciding acquisition for all the charging stations under his control and set the specific DSO as the only supplier. He also sets all charging stations to use only energy from the batteries until they are empty trying to save some money using before all the already purchased energy that is available.

2.1.2 Class diagram

The UML class diagram which describes the domain application is presented in figure 2.1. The User class is abstract and both EndUser and CPOW classes inherit from it since are the two different types of users of the whole system. Each EndUser owns vehicles and can book recharges which refer to them. Each recharge has a status and happens in a charging socket. Charging stations are composed of charging columns which are in turn composed of charging sockets and optionally also of batteries. There can be discounts associated to them. Each charging station refers to a specific eMSP. Each CPO administrates one and only one CPMS that manages one or more charging stations and can use DSOs to purchase energy forniture. There is a provisional class that is EnergyForniture, because at this stage of the project the best way to keep track of energy furniture is to separate them and locate different bills in different objects. This is meant in order to have a detailed report of the precise amount of energy purchased, its price and its destination since each energy forniture can refer to one/more batteries or directly to one/more charging sockets.

2.1.3 State charts

Charging process

In the state chart displayed in figure 2.2 the whole charging process is presented. This chart starts describing the booking process and all the requirements that have to be satisfied in order to make a correct booking of a charge (i.e. vehicle selection). For simplicity, we assume that the user is already logged in to the application and that the *select charging station* operation is meant to include also the type of socket if more options are available (i.e. fast charge socket). After the charge is booked, when the user inserts the plug of his vehicle into the socket the system enters the *Waiting charge completed* state, which is composed of two different states that describe the effective charging process. When the plug is removed the whole process ends. With this last action, we assume also that the payment is done at the moment of the plug removal since the found availability has been already checked during the booking phase.

Charging station energy supply

In the state chart displayed in figure 2.3 is described the state machine related to the energy supply types of a charging station. This representation has to be assumed to be applied independently to all the charging sockets of that specific charging station and the selection between batteries and network can be made manually by CPMS operators or dynamically by the system.

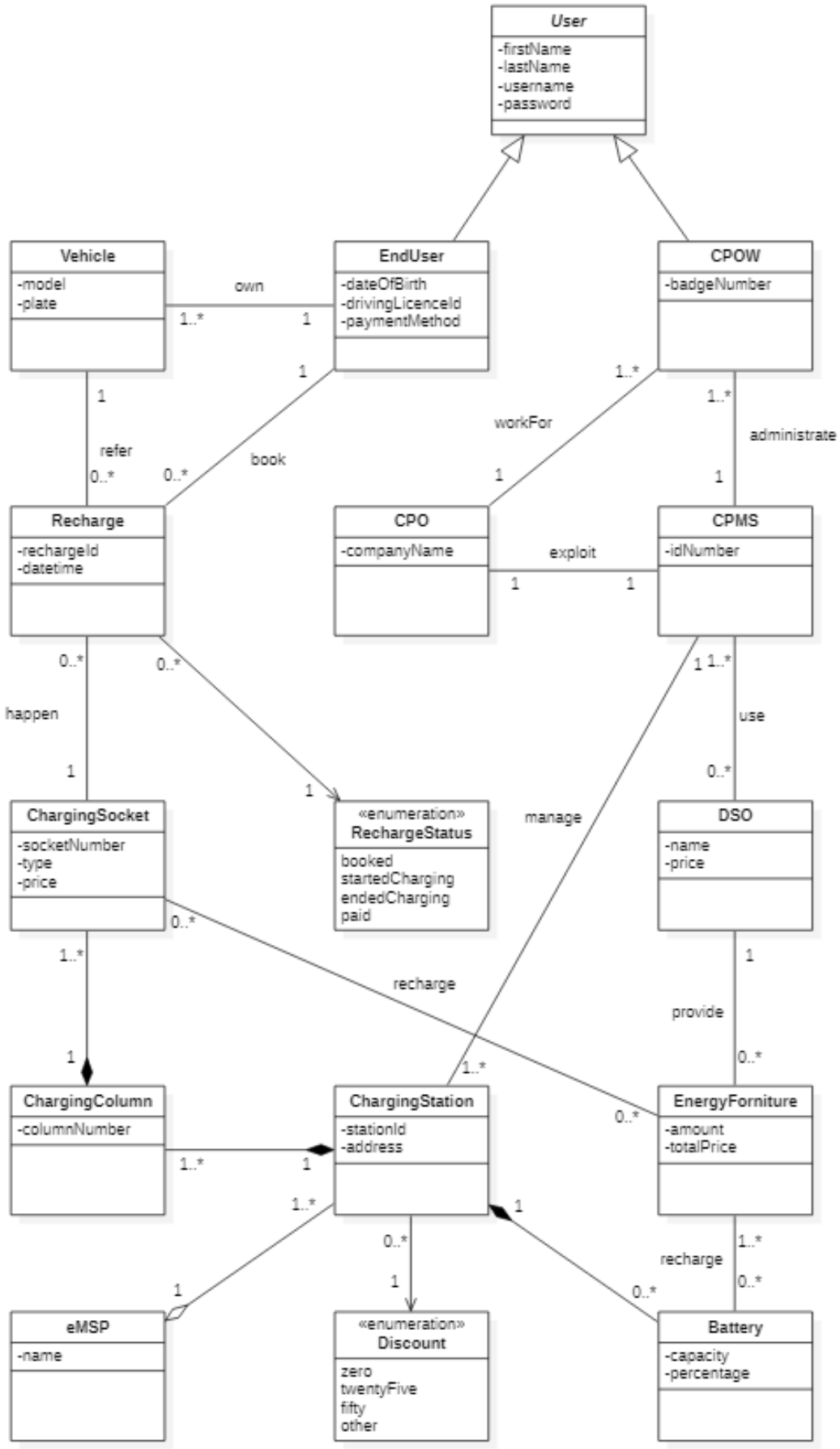

Figure 2.1: UML Class Diagram

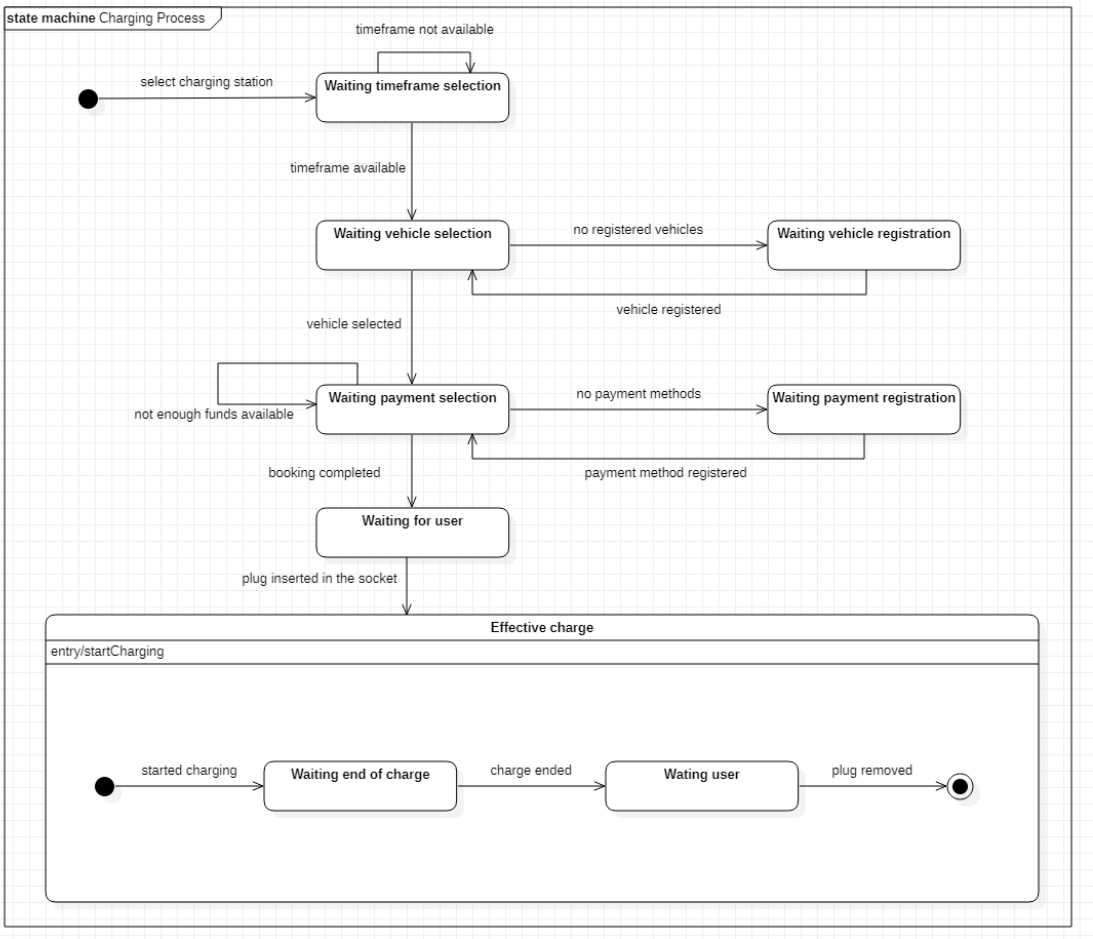

Figure 2.2: UML State Diagram for a whole charging process

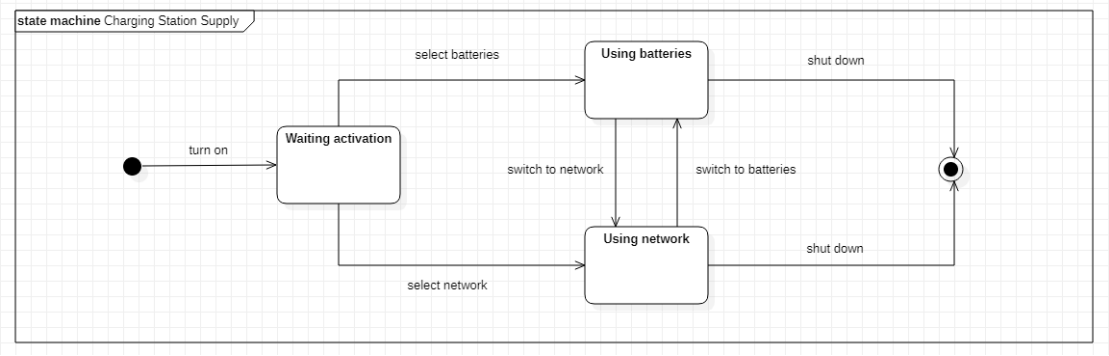

Figure 2.3: UML State Diagram for Charging Station energy supply

Other

Other objects are not represented in UML state charts since they don't change state at all during the system activities or the changes are too trivial to be represented in a diagram.

2.2 Product functions

In this section the most important functions that the eMall app will offer are presented divided by the type of user that will exploit them.

2.2.1 Unregistered user

Application exploring

When a user in not logged-in into the application the system will show a map containing the nearest charging stations and the related prices. This information can be accessed also in a list format where also some filters are available, but any operation (e.g. book a recharge) can't be performed until the login/registration.

End user registration

The system allows unregistered users to register and become effective end users of the application. They have to provide their first name, last name, username, password, date of birth and driving license ID. All these fields are mandatory in order to complete successfully the registration process. Optionally a user will be able to register a car and a payment method during the registration process, but this operation can also be performed later.

CPOW registration

The system allows newly hired CPOWs to set up their accounts in order to access the CPMS management web interface. They have to provide their first name, last name, username, password, and most important thing, their badge number. Also in this case, all fields are mandatory in order to complete successfully the registration process, otherwise, it will fail.

2.2.2 Authenticated end user

Here the focus is on the purpose of eMall on the end user side. In particular, we have two main functionalities.

Charge booking

The booking of a charge is the most important function that coincides with the main purpose of the whole system on the end user side. When a user is logged in, the system shows a map with all the nearest charging stations and lets the user navigate through them and sees current prices for different types of sockets of the different stations. Furthermore, the system will inform the user about special discounts and offers.

Once the user has selected a charging station and a date the system will show him all the available time frames and will allow completing the booking only if both a vehicle and a payment method with enough funds have been correctly selected. In all the other cases the operation couldn't be completed correctly.

Charging process

The system must manage also the whole charging process. So, when a user presses the charge button on the app and connects his car to the booked charging socket, the system will start dispensing energy to the car. All the process will be monitored by the system and the app will display to the user the remaining time and will send a notification to him once the process will be ended. At this point, the system will charge the import of the whole recharge on the payment method of the user.

2.2.3 Authenticated CPO worker

Now let's put focus on the CPO side.

Selecting from which DSO acquire energy

In normal execution, DSOs are selected dynamically by the system, trying to exploit the best quality/spent agreement based on prices and dates of different companies.

But can happen that a CPOW needs to manage the selection through his web interface. When he enters the related section, the system will show him a list of all the charging stations and for each one of them a list of DSOs available in that specific geographical area and their prices, with the possibility to turn off the auto-deciding process for each one of the stations and manually select a new DSO.

Charging station energy management

Also charging station use of energy in normal execution is managed dynamically by the system. In this case, the focus is to use batteries in order to exploit price swings in trying to reach the best level of revenue (e.g. when the energy price is low the system will use energy directly from the DSO to charge vehicles and recharge also batteries. On the other hand when the energy price increase over a certain threshold the system will, first of all, consume all energy in batteries bought at lower prices before acquiring new).

Also in this case a CPOW can, always through his web interface, go to the related section. The system will show him a list of all the charging stations and for each one of them, there is the possibility to set the price threshold or to directly manually manage the use of batteries or directly of the network.

Show charging station status

The system will also allow CPOWs to know both the internal and external status of each charging station. When a CPO access the related section on the web interface a list of all charging stations related to his CPO is shown. By clicking on one of them the station structure is shown (e.g. number of sockets and their types). Also current status is visible, so the list of both currently happening charges and booked charges are shown, with all the informations related to the interested vehicles.

2.3 User characteristics

The system has the following different types of users:

- *Unlogged user*: an unlogged user of the system can see charging stations near his position on the map and their prices but he can't do any type of operation (i.e. booking a charge). He can change his status by registering to the service or logging-in as *End User* or *CPO*.
- *End User*: is the main user of the system that can register vehicles, add payment methods, exploit special offers, and book and complete vehicle charges.
- *CPOW*: an operator which is related to a *CPMS* through which he can manage different charging stations (i.e. deciding to supply sockets from batteries or directly from the network), see *DSO* offers and manually decide from which of them purchase energy supplies.

2.4 Assumptions, dependencies and constraints

2.4.1 Domain assumptions

In the following rows domain assumptions are presented:

- [D1] Each CPO is associated with one and only one CPMS.
- [D2] All charging stations have been already correctly added in the right coordinates to third party map used.
- [D3] An End User can't disconnect the plug during the charging process.
- [D4] A unique identifier has been associated physically to every charging station.
- [D5] CPOs must manage their charging station only through his related CPMS.
- [D6] Energy can't be supplied by different DSOs at the same time to the same charging station.
- [D7] Charging sockets can't be supplied by both batteries and the network at the same time.
- [D8] Every end user make charges at the charging station with the specific vehicle he has booked for.
- [D9] The networks that allows the energy furniture from DSOs to charging sockets or batteries must work properly.
- [D10] The system exploits APIs to retrieve information about energy prices from different DSOs.
- [D11] Charging sockets are equipped with an *RFID* receiver in order to be unlocked.

2.4.2 Dependencies and constraints

Some third-party applications and dates from public institutions are necessary to make all functionalities of the system work properly.

- *Vehicle registering check*: check if inserted car model and plate exists.
- *Vehicle model information get*: get dates of all the electric vehicle models in commerce in order to know in advance which is the maximum battery capacity for each booked charge.

- *Payment method check*: check if the payment method added by the user works properly. It will be exploited also before every charge starts in order to ensure that on the payment method there are enough funds to complete a full charge.
- *Map service*: exploit a map service to show a map when the application starts.

3 Specific Requirements

3.1 External Interface Requirements

3.1.1 User Interfaces

eMall provides two different types of user interfaces, one for each type of user. In detail, end users exploit provided services through a mobile application, absolutely necessary to unlock charging sockets and start the charging process. On the other hand, CPOWs, which are meant like normal office workers, exploit their managing functionalities through a web application. Both interfaces have to satisfy accessibility requirements and, in particular, the mobile application must be user-friendly.

3.1.2 Hardware Interfaces

Since eMall is a software system, no specific hardware interfaces are provided to users. But clearly, end users will interact with charging station hardware (i.e. RFID receivers of charging sockets) that are already provided by domain assumptions. So the communication hardware of the mobile phone on which the mobile up runs is exploited.

3.1.3 Software Interfaces

Since no other applications need to retrieve any kind of data from eMall there are no software interfaces provided. But, like for Hardware Interfaces, the system exploits third-party software as reported in the dependencies section and also other APIs for information retrieval (e.g. DSOs prices) as declared in the domain assumption section.

3.1.4 Communication Interfaces

The whole eMall service is based on communication between different actors. Both the mobile app and CPMS communicate with the central eMall server through uniform internal APIs exploiting HTTPS protocol. In either the two subsystems type of communication is bidirectional, they need to send and receive data from the central server. For example, the mobile app must get updated availability of free charging slots but also update the central server when a booking is made. On the other side, also CPMS must always get updated information from the server, but also set, for example, a new DSO for a certain charging station.

Also communication with all the charging stations is necessary. In detail, the main server communicates with charging stations always through internal uniform APIs. Furthermore, RFID technology is exploited to allow communication between the mobile app and the charging socket

(i.e. for unlocking the charging socket). In particular, mobile phones communicate with the RFID receiver of the sockets.

All other types of communication, like the one with all third-party software presented in the dependencies section, happen through API, as the retrieval of DSOs prices.

3.2 Functional Requirements

- [R1] The system must allow unregistered/registered users to see a map of available charging stations and their prices and offers.
- [R2] The system must allow unregistered/registered users to see a list of charging stations and filter on it (e.g. offers, prices and positions).
- [R3] The system must allow unregistered users to register as end user or CPOW (if they have a badge id).
- [R4] The system must verify if the all data inserted by users are correct (e.g. personal data, vehicle and payment method information, charging station ID).
- [R5] The system must allow registered end users or CPOW to log in through their username and password.
- [R6] The system must allow registered end users to associate vehicles to their account and keep track of them.
- [R7] The system must allow registered end users to associate payment methods to their account.
- [R8] The system must allow registered end users to view the available time-slots for a certain type of socket of a certain charging station in a specific day.
- [R9] The system must allow registered end users to book a charge in a specific charging station.
- [R10] The system must allow end users to unlock a charging socket if they have booked it and it's the correct time-slot.
- [R11] The system must let a charge start if a vehicle is correctly connected and the charging socket is unlocked.
- [R12] The system must show to end users the charging status (e.g. remaining time to complete charge).
- [R13] The system must notify the end-user when the charge is complete.
- [R14] When a charging process is correctly finished the system must charge on the end user selected payment system the correct import.
- [R15] When a charging process is correctly finished the system must charge on the end user selected payment system the correct import.
- [R16] The system must allow CPOW to register a new charging station through its physical id.

- [R17] The system must be able to dynamically select if using batteries, directly the network or a mix of the two for each charging station.
- [R18] The system must allow CPOWs to manually select if using batteries, directly the network or a mix of the two for each charging station associated to them.
- [R19] The system must be able to dynamically select which DSO use to provide energy to a specific charging station.
- [R20] The system must allow CPOWs to manually select which DSO use to provide energy to a specific charging station associated to them.
- [R21] The system must be able to dynamically decides if a certain energy furniture is destinated to a battery or directly to sockets of charging stations .
- [R22] The system must allow CPOWs to manually decides if a certain energy furniture is destinated to a battery or directly to sockets of charging stations associated to them.
- [R23] The system must keep track of the current status of each charging process (e.g. booked, startedCharging, etc.).
- [R24] The system must keep track of the structure of each charging station (e.g. number of columns, number and type of sockets).
- [R25] The system must allow CPOWs to view the structure of each charging station associated to them.
- [R26] The system must keep track for each charging station of all bookings related to it.
- [R27] The system must allow CPOWs to view all the bookings of a certain charging station associated to them and their status.

3.2.1 Use cases

In this section the various use cases present in the use case diagram and derived from the scenarios previously described are illustrated in detail.

1. End-User registration

Actors: Non registered End-User

Entry condition:

- The End-User does not have an account and has the application opened

Flow of events:

- The End-User clicks on the "Login or Register" button.
- The End-User clicks on the "Register" button.
- The End-User clicks on the "I'm a User" button.
- The End-User provides name, surname, date of birth, email address, all information about his debit card and all information about his electric vehicles that he wants to register.

- The End-User provides username and password.
- The End-User clicks on the “confirm” button.

Exit conditions:

- A successful message is sent to the End-User which is redirected to the main page of the account

Exceptions:

- The personal information are not correct. The system shows an error message and asks the End-User to re-write the incorrect ones.
- Debit Card information are not correct. The system shows an error message and asks the End-User to re-write the incorrect ones.
- Electric vehicle information are not correct. The system shows an error message and asks the End-User to re-write the incorrect ones.
- The username was already taken by another user. The system shows an error message and asks the End-User to choose another username.
- The End-User interrupts the registration process clicking to "exit" button. He’s redirected to the main page

2. End-User charge booking from searching panel

Actors: End-User

Entry condition:

- Registered End-User opened the app and logged in.

Flow of events:

- The End-User clicks on "book a charge" button.
- The End-User clicks on "search charging station" button.
- The End-User provides the name of a charging station, clicks on "search" and then select it.
- The End-User selects a Day and a type of a socket.
- The End-User selects one of the free time-slots available.
- The End-User selects an electric vehicle associated to his account.
- A summary of the booking with the total cost is displayed.
- The End-User clicks on the "Confirm" button.

’ Exit conditions:

- A successful message which presents the summary of the booking with also the number of associated charging column , number of associated socket, and the booking id is sent to the End-User.

Exceptions:

- The inserted charging station doesn't exists. The system shows an error message and asks the End-User to re-write the research it.
- There are no socket of that type available for that day. The system shows an error message and asks the End-User to change the date.
- The End-User interrupts the registration process clicking to "exit" button. He's redirected to the main charge booking page

3. End-User charge booking from the map panel

Actors: End-User

Entry condition:

- Registered End-User opened the app and logged in.

Flow of events:

- The End-User clicks on "book a charge" button.
- The End-User clicks on "browse map" button.
- The End-User clicks on a charging station in the map.
- The End-User selects a Day and a type of a socket.
- The End-User selects one of the free time-slots available.
- The End-User selects an electric vehicle associated to his account.
- A summary of the booking with the total cost is displayed.
- The End-User clicks on the "Confirm" button.

Exit conditions:

- A successful message which presents the summary of the booking with also the number of associated charging column, number of associated socket and the booking id is sent to the End-User.

Exceptions:

- There are no socket of that type available for that day. The system shows an error message and asks the End-User to change the date.
- The End-User interrupts the registration process clicking to "exit" button. He's redirected to the main charge booking page

4. End-User benefits from a special offer from the offers panel

Actors: End-User

Entry condition:

- Registered End-User opened the app and logged in.

Flow of events:

- The End-User clicks on "book a charge" button.
- The End-User clicks on "list special offers" button.
- The End-User selects a certain offer of a certain charging station.
- The End-User selects a Day and a type of a socket.
- The End-User selects one of the free time-slots available.
- The End-User selects an electric vehicle associated to his account.
- A summary of the booking with the total cost is displayed.
- The End-User clicks on the "Confirm" button.

Exit conditions:

- A successful message which presents the summary of the booking with also the number of associated charging column, number of associated socket and the booking id is sent to the End-User.

Exceptions:

- The selected type of socket and/or the selected day is not considered in the special offer. The system shows an error message and asks the End-User to change it/them.
- There are no socket of that type available for that day. The system shows an error message and asks the End-User to change the date.
- The End-User interrupts the registration process clicking to "exit" button. He's redirected to the main charge booking page

5. End-User benefits from a special offer from the map panel

Actors: End-User

Entry condition:

- Registered End-User opened the app and logged in.

Flow of events:

- The End-User clicks on "book a charge" button.
- The End-User clicks on "browse map" button.
- The End-User clicks on "visualize special offers" button.
- The End-User clicks on a charging station in the map.
- The End-User selects a Day and a type of a socket.
- The End-User selects one of the free time-slots available.

- The End-User selects an electric vehicle associated to his account.
- A summary of the booking with the total cost is displayed.
- The End-User clicks on the "Confirm" button.

Exit conditions:

- A successful message which presents the summary of the booking with also the number of associated charging column, number of associated socket and the booking id is sent to the End-User.

Exceptions:

- The selected type of socket and/or the selected day is not considered in the special offer. The system shows an error message and asks the End-User to change it/them.
- There are no socket of that type available for that day. The system shows an error message and asks the End-User to change the date.
- The End-User interrupts the registration process clicking to "exit" button. He's redirected to the main charge booking page

6. End-User vehicle charging

Actor: End-User

Entry condition:

- The End-User has previously booked a charge and now is at the charging station near the associated charging column with his vehicle. He also has the application opened displaying the page of the booking.

Flow of events:

- The End-User clicks on "unlock charging column" button.
- A successful message is displayed and the associated socket of the booked charging column became available.
- The End-User connects his vehicle to the socket.
- The charging process starts automatically and the charging column displays progressively the amount of charge done. Also the application displays that the charge is going correctly.
- When the charge ends the charging column displays a message.
- The End-User disconnects the vehicle from the socket.
- The End-User clicks, on the application, on "end charge" button.
- The used socket of the charging column is blocked.

Exit conditions:

- The system makes the payment and displays a successful message to the End-User.

Exceptions:

- The End-User has arrived too late and the booking has been expired. The system shows an error and deletes the booking.
- The End-User has arrived too early respects to the time-slot of the booking and is not able to click on "unlock charging column" button.
- The charging process cannot be doing correctly. The system shows an error message, displays a list of possible solutions to solve the problem and displays a list of possible solutions to solve the problem.
- The payment has not been successful. The system shows an error message indicating that the balance is still to be paid and displays a list of possible solutions to solve the problem.

7. End-user personal charge booking view

Actor: Registered End-User

Entry condition:

- Registered End-User opened the app and logged in.

Flow of events:

- End-User clicks on "my Bookings" button.

Exit conditions:

- All available charge bookings are displayed and the End-User can select one of those in order to see a summary of that booking.

Exceptions:

- No charging booking have been made, the systems shows a message which says that the list is empty.

8. CPOW registration

Actors: Non registered CPOW

Entry condition:

- The CPOW does not have an account and has the application opened

Flow of events:

- The CPOW clicks on the "Login or Register" button.
- The CPOW clicks on the "Register" button.
- The CPOW clicks on the "I'm a CPO Worker" button.
- The CPOW provides name, surname, date of birth, email address, the associated ID of the CMPS where he works and a special code provided by his employer.
- The CPOW provides username and password.

- The CPOW clicks on the “confirm” button.

Exit conditions:

- A successful message is sent to the CPOW which is redirected to the main page of the account

Exceptions:

- The personal information are not correct. The system shows an error message and asks the CPOW to re-write the incorrect ones.
- The CMPS ID is incorrect or doesn’t exists. The system shows an error message and asks the CPOW to re-write it.
- The username was already taken by another User. The system shows an error message and asks the CPOW to choose another username.
- The CPOW interrupts the registration process clicking to "exit" button. He’s redirected to the main page

9. CPO new charging station registration

Actors: Registered CPOW

Entry condition:

- Registered CPOW opened the app and logged in.

Flow of events:

- The CPOW clicks on the "Charging Stations" button.
- The CPOW clicks on the "New Charging Station" button.
- The CPOW provides charging station name, position and ID.
- The CPOW clicks on the “confirm” button.

Exit conditions:

- A successful message is sent to the CPOW

Exceptions:

- Charging station information are incorrect or it doesn’t exists. The system shows an error message and asks the CPOW to re-write it.
- The CPOW interrupts the registration process clicking to "exit" button. He’s redirected to the main page

10. CPO DSOs offers view

Actor: Registered CPOW

Entry condition:

- Registered CPOW opened the app and logged in.

Flow of events:

- The CPOW clicks on "View DSOs Offers" button.
- A list of all DSOs offers is displayed.
- The CPOW clicks on "Energy Source" button and then selects one or more energy sources.

Exit conditions:

- All offers related to DSOs that doesn't offer energy from the energy source selected by the CPOW are discarded from the previous list. CPOW can select one of the new list in order to display a page with further details about that offer.

Exceptions:

- There are no DSOs offers of the selected energy source, the systems shows a message which says that the list is empty.

11. CPO energy purchasing from DSO

Actor: Registered CPOW

Entry condition:

- Registered CPOW opened the app, logged in and listed DSOs offers.

Flow of events:

- The CPOW clicks on a certain DSO offer.
- A page with all information about that offer is displayed.
- The CPOW clicks on "Acquire energy from this DSO".
- The CPOW inserts the start date, end date, and the amount of energy in kilowatt hour.
- The CPOW clicks on "Go to Purchase" button.
- A summary of the purchase with the total cost and energy delivery starting estimated date is displayed.
- The CPOW clicks on "Confirm" button.

Exit conditions:

- The system makes the payment and a displays a successful message to the CPOW.

Exceptions:

- The conditions inserted by the CPOW cannot be satisfied by the DSO. The system shows an error and asks the CPOW to re-write them.
- The payment has not been successful. The system shows an error message and invites the CPOW to retry.

- The CPOW interrupts the purchasing process clicking to "exit" button. He's redirected to the main page of the account.

12. CPO batteries management

Actor: Registered CPOW

Entry condition:

- Registered CPOW opened the app and logged in.

Flow of events:

- The CPOW clicks on "Batteries Management".
- The list of all associated batteries of the charging station are displayed.
- The CPOW clicks on one of those.
- A page with all features of the battery is displayed.
- The CPOW clicks on "Store Energy Into This Battery".
- The CPOW clicks on "Confirm" button.

Exit conditions:

- The system starts the energy storing process and then shows a successful message to the CPOW.

Exceptions:

- The are no available batteries. The systems shows a message which says that the list is empty.
- The energy storing process doesn't work properly. The system stops it, shows an error message to the CPOW and displays a list of possible solutions to solve the problem.

13. CPO energy supply decision

Actor: Registered CPOW

Entry condition:

- Registered CPOW opened the app and logged in.

Flow of events:

- The CPOW clicks on "Energy Supply" button.
- A list of all associated charging stations is displayed.
- The CPOW clicks on one of those.
- A list of all DSOs services purchased and of all charged batteries available with a brief summary of their main features for each of them are displayed.

- The CPOW clicks on one of the DSOs services.
- The CPOW inserts the amount of energy in kilowatt hour, a starting date and an ending date.
- The CPOW clicks on one of the batteries.
- The CPOW inserts the amount of energy in kilowatt hour, a starting date and an ending date.
- The CPOW clicks on "Continue" button.
- A summary of the total energy supply with the percentages of energy provided by each selected service with respects to the total energy used is displayed.
- The CPOW clicks on "Confirm" button.

Exit conditions:

- The system starts the energy transfer process and then shows a successful message to the CPOW.

Exceptions:

- There are no charging stations available. The systems shows a message which says that the list is empty.
- There are no DSOs services purchased and/or charged batteries available. The systems shows a message which says that the list is empty.
- The amount of energy selected is higher than the available one. The system shows an error message and invites the CPOW to re-write it.
- The starting and ending date selected doesn't match with the delivering period indicated in the DSO's offer. The system shows an error message and invites the CPOW to re-write it.
- The energy transfer process doesn't work properly. The system stops it, shows an error message to the CPOW and displays a list of possible solutions to solve the problem.
- The CPOW interrupts the process clicking to "exit" button. He's redirected to the main page of the account.

14. CPO associated charging stations view

Actor: Registered CPOW

Entry condition:

- Registered CPOW opened the app and logged in.

Flow of events:

- The CPOW clicks on "Charging Stations" button.
- A list of all associated charging stations is displayed.

- The CPOW clicks on one of those.

Exit conditions:

- A page with all features of the selected charging station is displayed.

Exceptions:

- There are no charging stations available. The systems shows a message which says that the list is empty.

In the following table is shown which goals are involved in every use case.

3.3 Performance Requirements

Performances are particularly critical for eMall system. On the end user side, all operations have to be performed as fast as possible and in the correct order, e.g. overbooking of charging sockets must be avoided. Those specifications must fit also end users with low-speed internet connections. Also on the CPMS side all operations, like switching from battery power to network power, must be performed in less than 1 second. All the computing infrastructure must be thought to be scalable, in order to allow future server capacity to increase due to the increasing number of users.

3.4 Design Constraints

3.4.1 Standards compliance

3.4.2 Hardware limitations

3.4.3 Any other constraint

3.5 Software System Attributes

3.5.1 Reliability

3.5.2 Availability

3.5.3 Security

3.5.4 Maintainability

3.5.5 Portability

4 Formal Analysis using Alloy

5 Effort spent

6 References