POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

eMall – e-Mobility for all

Requirement Analysis and Specification Document - RASD

Author(s): **Fabio Lusha - 10882532**

Bianca C. Savoiu Marinas - 10684465

Academic Year: 2022-2023

Contents

1 | Introduction

1.1. Purpose

Widespread electrification of transport is the most efficient way to reach Europe's climate objectives for the sector and electric charging is the main asset to overcome the obstacles of the take-up of electric vehicles (EVs). EVs can reduce CO2 by an estimated annual 600,000 tons by 2030, going towards a carbon neutral Europe, and the importance of this aim raises the problem of having efficient systems that manage the charging services. The eMall is thought as an all-encompassing application that oversees the entire process from the user interaction to the effective recharge of the EV's battery.

The main goal we want to achieve with the eMall software is to help The EVDs (electric vehicle drivers) to have a better access to recharge and to be able to book a charging point in order to avoid interference with his daily plans. Another important purpose of the system is to safeguard not only the users but also the providers of the service and this is made through privacy agreements and the actual interaction, that guarantees to supervise both interested parts, in order to get the best possible service and pay for it accordingly, having also a technical and economic exploitation of the charging infrastructures.

In this context there is an increase in the requested electric energy, but large amounts of power in short periods would require investments in the reinforcement of the distribution networks, which have not been designed to accommodate such load. It becomes necessary to introduce new systems and solutions to optimize the operation of the distribution networks. In this context we can identify the DSOs as the suppliers of electricity through the distribution networks. The DSOs interact with the eMall, and in particular with the CPMS (Charging Point Management System) module of the system to be. The CPMS, then, gives the information about the DSO's supply to the CPOs, which are important actors, that use the system in order to manage the charging service. A CPO is represented by an employee or a software, part of the business that owns some charging stations and wants to manage them through the eMall, deciding from where to acquire energy, and how to establish the prices, the special offers and other details about the stations.

The eMall is thought as a software that manages both the interaction with the businesses that offer the charging service and the interaction with the EVDs which want to use these services in order to charge their EVs. Therefore, the eMall provides a mobile application (eMma), which through its interface allows to the EVD to obtain the service, and provides, also, a web application that the CPOs use to manage the charging stations. The EVD interacts, as well, with the charging point interface (eMci), that communicates with the CPMS part of the eMall, in order to start the charging session from the station, plugging then the car to the compatible connector to effectively charge the EV.

Goals In the following table we present the main goals of the software to be. The goals capture the needs of the stakeholders, which are the EVDs and the CPOs.

Goal	Description
G1	The EVD is able to identify the charging stations nearby
G2	The EVD is able to visualize the tariffs of the charging stations
G3	The EVD is able to visualize any special offer available at the charging station
G4	The EVD is able to book a charge in a specific charging station for a certain time frame
G5	The EVD is able to start the charging process at a certain station
G6	The EVD is able to pay for the obtained service
G7	The CPO can decide from which DSO to acquire energy
G8	The CPO can decide the cost of charging
G9	The CPO can set special offers
G10	The CPO can decide whether to store or not energy in batteries
G11	The CPO can decide whether to use the energy available in the batteries

Table 1.1: Goals

1.2. Scope

World phenomena The portion of the real world where the machine is to be deployed and used is called the environment. Hence, scoping the problem by defining the environment is paramount, and this is the target of the next table. With the world phenomena we define the environment in which the software to be will operate, by clarifying some facts about the world and the users. In the following chapter, to the environment will be also given some boundaries, making some assumptions and describing some domains properties, but this is not an aspect tackled by the next table of phenomena.

World phenomena	Description
WP1	The EVD wants to charge the EV's battery
WP2	The EVD wants to plan where and when to charge the EV's battery, so he needs to know the position on the territory of the charging stations and if there are available and compatible charging points
WP3	The EVD wants to know the price and any special offers of the charging stations, to choose the one that better suits his needs
WP4	The prices of energy often vary in real world economy
WP5	The DSOs, as marketing strategy, have special offers during certain time periods.
WP6	The DSOs provide energy to the charging stations
WP7	The DSOs decide the energy price
WP8	The providers of the charging service (CPOs) make special offers during certain time periods
WP9	The CPOs decide the price of charging, following marketing trends, and depending on DSOs prices and business decisions
WP10	EVs may have an integrated rectifier that converts AC electricity to DC
WP11	Some type of chargers have an integrated rectifier that converts AC electricity to DC. They supply the EV directly with DC current
WP12	A charging of type X, provides electricity in mode C and is given through Z connectors
WP13	A charging station is owned and managed by one CPO
WP14	A CPO owns and manages one or more charging stations
WP15	The CPO buys energy from the DSOs
WP16	A charging station may be equipped with batteries
WP17	Charging stations equipped with batteries grant more flexibility to CPOs on how to choose between the energy stored in the batteries and the one offered by DSOs
WP18	Low voltage (3.7 - 11 kW) chargers need more time to charge the battery
WP19	Medium voltage (22-90 kW) chargers need less time to recharge a battery of capacity C than a low voltage charger

WP20	High voltage ($>$ 90 kW) chargers need less time to recharge a battery of capacity C than a medium voltage charger
WP21	Batteries can only be charged with direct current (DC) electric power
WP22	Given a continuous supply of power W, and a battery with finite capacity C, than the charging time T is finite.
WP23	A battery can store a finite amount of energy, given by its capacity C.
WP24	The charging point of a specific charging station may be unusable because of maintenance or faults
WP25	The DSOs distribute and manage energy from the generation sources
WP26	Most electricity is delivered from the power grid as alternating current (AC)
WP27	During the day the electric power supplied to the station can vary
WP28	During the day a short-duration reduction in the voltage supplied to the electrical power systems may occur due to high current demand or faults in the system.
WP29	During the day a momentary increase in voltage may occur. This may happen when a heavy load turns off in a power system.
WP30	The DSOs operate and manage the electricity distribution networks
WP31	The DSOs solve grid problems, such as faults and network breaks

Table 1.2: World Phenomena

Shared phenomena The shared phenomena define the interface through which the machine interacts with the world. The software monitors some shared phenomena, while controls others, and to show when the software takes the part of the controller and when the part of the observer we created two more columns in the next table, to keep track of the initiator of the action, in case the natural language turns out to be ambiguous. So, in the following assertions we present an interaction between the world (users and external systems) and the machine (the eMall, especially its interfaces, such as the eMma, the eMci and the managerial web application).

Shared phenomena	Description	Controller	Observer
SP1	The eMall notifies the EVD when the charging process is finished	eMall	EVD
SP2	The EVD creates an account	EVD	eMall
SP3	The EVD in order to register inserts in the mobile app of the eMall the personal data (name, surname, email, password, payment details)	EVD	eMall
SP4	The EVD logs in using the email and the password	EVD	eMall
SP5	The EVD accepts the terms of service in order to use the eMma	EVD	eMall
SP6	The EVD shares its location with the eMall	EVD	eMall
SP7	The EVD confirms the payment from the mobile application of the eMall	EVD	eMall
SP8	The EVD deletes previously inserted EVs from its account	EVD	eMall
SP9	The EVD updates the specifications of the EVs on its account	EVD	eMall
SP10	The EVD adds a new EV to its account	EVD	eMall
SP11	The EVD inserts the maximum and minimum current supported by the EV	EVD	eMall
SP12	The EVD inserts the maximum power supported by the EV	EVD	eMall
SP13	The EVD inserts the inlet type of the EV	EVD	eMall
SP14	The EVD inserts whether the EV is equipped with a built-in rectifier	EVD	eMall
SP15	The EVD inserts the capacity of the battery in kWh	EVD	eMall

SP16	The eMall shows to the EVD the map of the charging stations nearby his location	eMall	EVD
SP17	The EVD chooses a charging station from the map	EVD	eMall
SP18	The eMall shows the user the rating of the charging station	eMall	EVD
SP19	The EVD inserts the expected time when he plans to start the charging process	EVD	eMall
SP20	The EVD inserts the expected time when he plans to end the charging process	EVD	eMall
SP21	The eMall shows to the EVD the list of available chargers of the charging station	eMall	EVD
SP22	The eMall shows the charger type and its connectors	eMci / eMma	EVD
SP23	The EVD chooses the charger he wants to use from the list of available ones	EVD	eMall
SP24	The eMall shows to the EVD the charger costs (per kWh, per minute, additional costs)	eMma/eMci	EVD
SP25	The eMall shows to the EVD the status of the charger	eMci	EVD
SP26	The eMall shows to the EVD the battery level of the connected EV	eMci	EVD
SP27	During the charging session the eMall shows to the EVD the power output of the charger	eMci	EVD
SP28	During the charging session the eMall shows to the EVD the remaining time to complete the charging process	eMci	EVD

SP29	The EVD starts the charging session from the charger	EVD	eMSP
SP30	*The CPMS asks the DSO about the current available energy sources, their prices, and special offers*	CPMS	DSO
SP31	The DSO dynamically changes the price of electricity	DSO	CPMS
SP32	The DSO changes dynamically the *energy sources* from which acquires energy	DSO	CPMS
SP33	The DSO makes special offers	DSO	CPMS
SP34	The CPO logs in	CPO	CPMS
SP35	The CPO selects the charging station for which to set the parameters (price, energy) of the charging service	CPO	CPMS
SP36	The CPO selects the DSO from which to acquire energy	CPO	CPMS
SP37	The CPMS shows to the CPO the *energy sources* and the relative current prices and special offers of the DSO	CPMS	DSO
SP38	The CPO sets the cost of charging	CPO	CPMS
SP39	The CPO can set a special offer	CPO	CPMS
SP40	The CPO selects the energy sources from which to acquire energy	CPO	CPMS
SP41	The CPMS shows if there are available batteries in the charging station	CPMS	CPO
SP42	The CPO selects the battery in which to store energy	CPO	CPMS
SP43	The CPO sets the amount of energy to store in the battery	CPO	CPMS
SP44	The CPMS dynamically shows to the CPO the number of EVs charging	CPMS	CPO

SP45	The CPMS dynamically shows to the CPO the charging stations consumption of energy	CPMS	CPO

Table 1.3: Shared Phenomena

1.3. Definitions, Acronyms, Abbreviations

1.3.1. Abbreviations

- **eMall**: e-Mobility for all
- **eMma**: e-Mall mobile application
- **eMci**: e-Mall charger interface
- **CPMS**: Charging Point Management System
- **CPO**: Charge Point Operator
- **eMSP**: Electric Mobility Service Providers
- **DMS**: Distribution Management System
- **DSO**: Distribution System Operator
- **EV**: Electric Vehicle
- **EVD**: Electric Vehicle Driver
- **EVSE**: Electric Vehicle Supply Equipment
- **HV**: High Voltage
- **LV**: Low Voltage
- **MV**: Medium Voltage
- **SCADA**: Supervisory Control and Data Acquisition
- **SCM**: Smart Charging Management
- **OMS**: Outage Management System
- **AC**: Alternating current

- **DC**: Direct current

1.3.2. Definitions

- **DSO**: typically the entity responsible for the operation and management of distribution networks – High, Medium and Low Voltage networks. For this purpose, the DSO typically owns systems such as Supervisory and Control Data Acquisition (SCADA)/ Distribution Management System (DMS) for the monitoring and general overview of the state of the network. It also owns other systems such as the Outage Management System (OMS) and Work Force Management System (WFMS) for addressing the network operation problems related with the continuity and quality of service.
- **CPO**: entity that technically manages all the EV infrastructure assets, depending of existing country regulation – this role can be assured by the DSO or other entity.
- **eMSP**: is the entity that can explore the economic side of the EV charging infrastructure, namely by selling energy for charging purposes.
- **CPMS**: is a software system that manages the charge point infrastructure – can manage the technical and economic aspects of the charging infrastructures.
- **EVD**: person or entity who owns an EV car and can use the public or private facilities for charging purposes.
- **EVSE**: Electric Vehicle Supply Equipment. It is an equipment that is able to charge EV batteries with AC or DC loads and with different rated powers depending on the type of equipment.
- **Private parking**: can be a condominium, industry or other entity who has private owned EV
- **Voltage sag**: a short-duration reduction in voltage of an electric power distribution system. It can be caused by high current demand or fault current elsewhere in the system.
- **Voltage swell**: the opposite of voltage sag. Voltage swell, which is a momentary increase in voltage, happens when a heavy load turns off in a power system.
- **Socket outlet**: the port on the electric vehicle supply equipment (EVSE) that supplies charging power to the vehicle
- **Plug**: the end of the flexible cable that interfaces with the socket outlet on the

EVSE.

- **Cable**: a flexible bundle of conductors that connects the EVSE with the electric vehicle
- **Connector**: the end of the flexible cable that interfaces with the vehicle inlet
- **Vehicle inlet**: the port on the electric vehicle that receives charging power
- *Inverter*: It is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC).
- **Rectifier**: an electrical device that converts alternating current (AC) to direct current (DC).
- **eMma**: the eMSP subsystem responsible for the EVD interaction from the mobile app
- **eMci**: the eMSP subsystem responsible for the EVD interaction at the charging point
- ***additional costs****: overtime penalty, deposit for unregistered users*
- **Status of the charger**: can be free, occupied, booked and in maintenance
- **Smart meter**: is an electronic device that records information such as consumption of electric energy, voltage levels, current, and power factor; allow the reading of energy flow and real-time usage, and consequently permit the identification of interruptions in energy flow

1.4. Reference Documents

- `IEEE 29148-2018 International Standard - Requirements engineering`: defines the construct of a good requirement and provides attributes and characteristics of requirements; provides also additional guidelines for applying the requirements and requirements-related processes
- `RDD` assignment document
- `Electric Vehicle CPMS and Secondary Substation Management by F. Campos, Efacec, Portugal; L. Marques, Efacec, Portugal and K. Kotsalos, Efacec, Portugal (15 October 2018)`: used to define the interactions between the different parts of the system and the actors; models the EV public infrastructures, the

eMSP, the DSO and the CPMS together with the APIs and protocols that allow their communication

- `EV CHARGING: HOW TO TAP IN THE GRID SMARTLY? by Platform for Electromobility (May 2022)`: used to understand the environment of the problem and contextualize the analysis

1.5. Document Structure

This document mainly follows the guidelines of the `IEEE 29148-2018 - International Standard - Requirements engineering`, with some changes in the order of the contents. Also in the final part of the document is present an `Alloy` formal analysis of the described model, an additional section with respect to the standard. The document is composed by the following parts:

- An introduction to the domain in which the system will operate (world phenomena) and an initial description of the software to be, the eMall, specifying the goals to achieve
- The overall description of the functions that the eMall has to implement specifying the requirements and a domain model, its interaction with the different users describing with diagrams the most important shared phenomena, and the domain assumptions necessary to the system to be
- A thorough list of requirements both functional and non functional: giving a detailed description of the functional requirements using use cases, use cases diagrams and UML sequence diagrams to better specify the interactions; and characterizing the non functional requirements through software system attributes
- A formal analysis using alloy in order to show the soundness and correctness of the model described in the document, considering only a part the most important requirements of the system
- A section that contains the effort spent by the members of the group working towards the completion of this document

2 | Overall description

In this chapter a general overview of our software to be and its functionalities is given. In section 2.1 we will present a conceptual model of the domain we are working in, where, in addition to the real world objects that are significant in our domain and to our system, we include the main components of our system that will interface with the environment. Then, we proceed by presenting the state diagrams of the most important scenarios discussed in the following subsection. In section 2.2 we give a description of the main functionalities our system has to provide, but without going in much detail since we will delve into this aspects in the next chapter. In section 2.3 we provide an analysis of the target users of the system, which are the clients that will use the system or will interact with it. Finally, in section 2.4, we outline the assumptions, the dependencies and the constraints, necessary to be taken into account when implementing the software.

2.1. Product perspective

2.1.1. Domain model

We start off this chapter by analyzing the domain model (or *conceptual model*) we came up with to represent the domain we are working in. Being a conceptual model the diagram was not drafted with all the formalism specified in the UML notation; we actually used a pretty informal description, specifying multiplicity and reading direction only when strictly necessary. The model in figure 2.1 was drawn using the UML class diagram notation, and illustrates only the conceptual classes that are significant to the domain [1]. We also included the classes representing the component of our system to be that will interact directly with the environment.

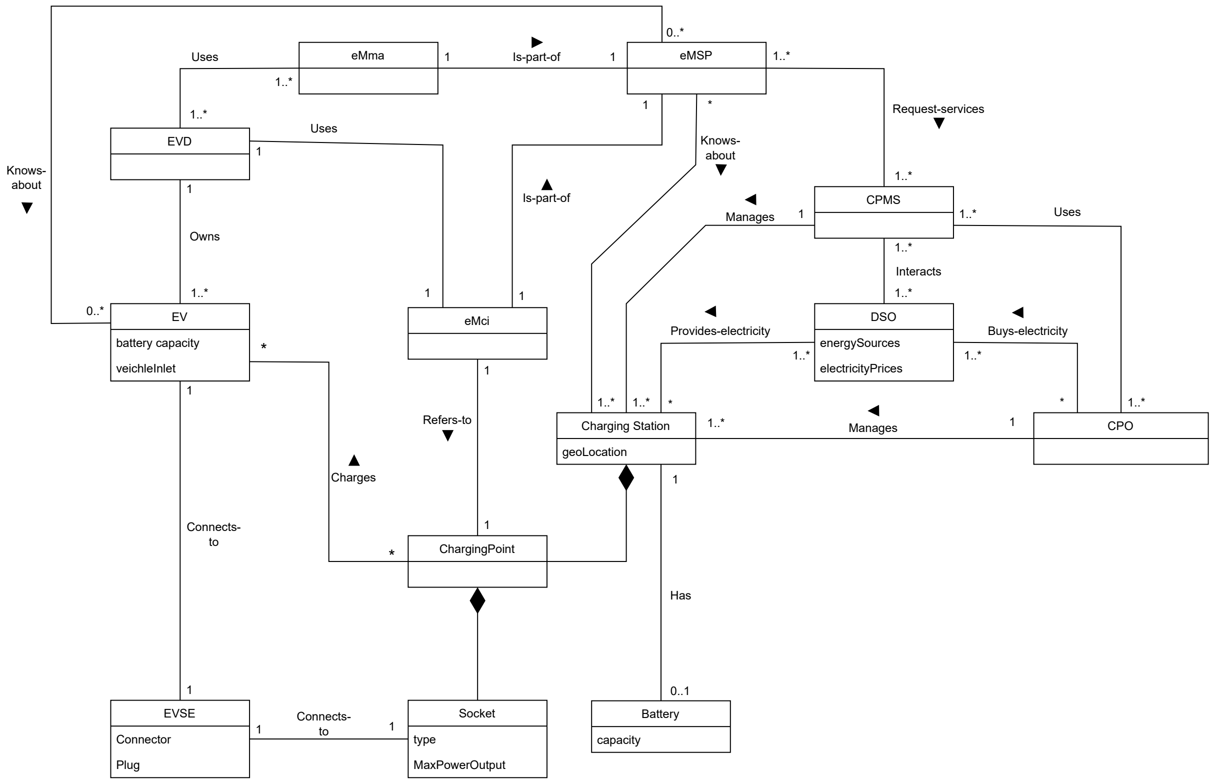

Figure 2.1: Domain model

We now proceed discussing some of the elements that may not be so immediate only by reading the domain model.

EVSE The EVSE, as mentioned in 1.3, is a general term that refers to the the equipment that allows a vehicle to be recharged. In this context we can see it as a universal adapter that can be an interface for the vehicle inlet and the socket of the charging point. In the diagram this is shown by the association *'Connects-to'* for both class EV and Socket. The multiplicity one-to-one for both associations is to show that at a specific moment a vehicle can be connected to a socket only through one single EVSE [1]. Obviously, an EV can connect to all the EVSEs that have a connector compatible with its inlet, and a Socket can connect to all the EVSEs that have a compatible plug. It also should be noticed that there are charging points that do not expose the socket directly, but they have an EVSE integrated, namely a cable with it's connector.

DSO In the model the DSO is represented as interacting with both CPO and the CPMS. This happens because we do not distinguish between the actual business and the Information System he uses. So the association between DSO and CPMS is to be intended as the interaction between the two software systems, meanwhile, the association between

DSO and CPO represents the interaction of the two businesses.

ChargingPoint This class represents the actual physical device that contains the sockets to which the EV will connect to charge.

Battery In the association *'Has'* between ChargingStation and Battery we have stated that an instance of ChargingStation may have only one Battery. The reason behind this decision is that we opted for a high level of abstraction and with the class Battery we mean a generic mean of energy storage, without concerning ourselves with the actual physical properties or requirements of the item itself.

CPO The multiplicity one-to-many in the association *'Uses'* between CPO and CPMS is motivated by our view of the system. In our perspective, the CPMS is viewed as a software that is offered to different businesses that manage their charging stations, thus a business through the CPO can choose to manage the charging stations with different CPMS systems.

2.1.2. State charts

Among the main interactions with the eMall we have decided to represent here with state diagrams the ones that we consider the most interesting and complex uses of the system, from EVD point of view: the initiation of a charging station and the booking operations.

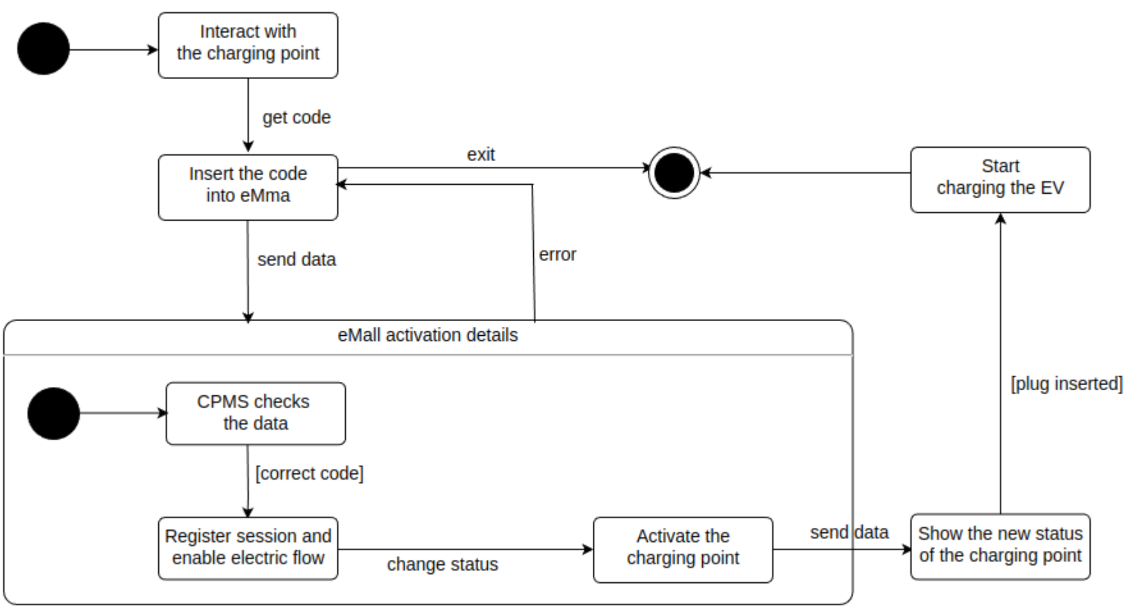

Figure 2.2: State diagram of the EVD that starts a charging session

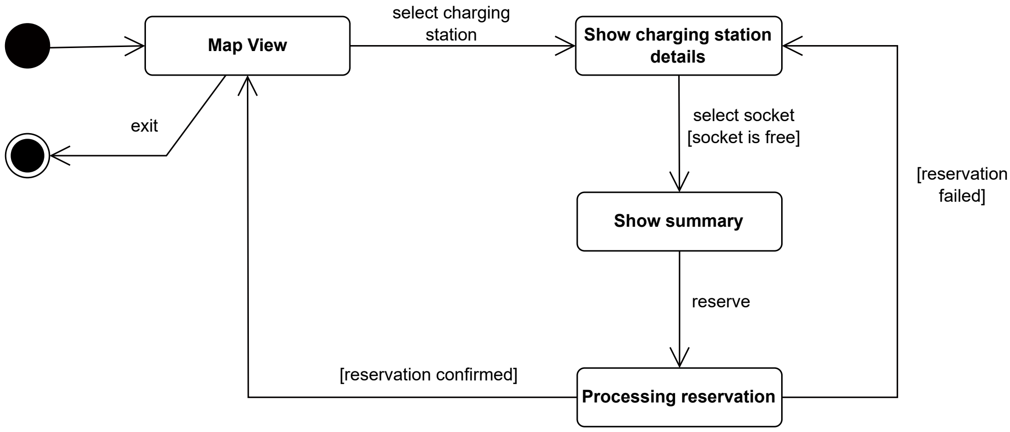

Figure 2.3: State diagram of the EVD that books a charging point

We also report another state diagram to represent the main interaction of the CPO with the managerial part of our software. We consider the case in which the CPO wants to modify some parameters regarding a certain charging station.

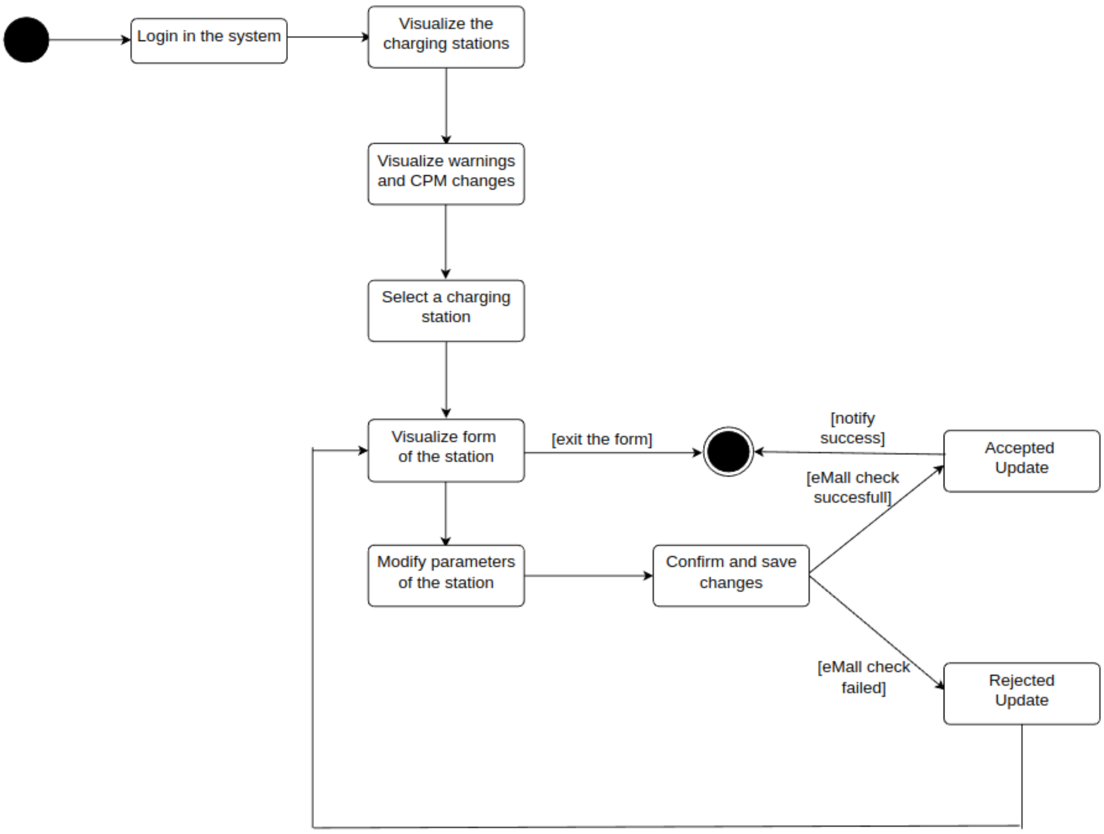

Figure 2.4: State diagram of the CPO that manages charging stations

2.1.3. Scenarios

Booking a charging socket Edward, after getting in his electric vehicle, notices that the battery is at low percentage, so he plans to book a charge at a station nearby. He grabs the smartphone and opens the mobile app eMma to look for a charging station. When Edward opens the app he is greeted with the view of a map showing him the nearest charging stations to his location. The charging stations are represented with icons of different colors. The colors are used to distinguish totally occupied charging stations from those with free sockets where to charge. After moving around the map, Edward finds a charging station with free sockets suitable to his needs. He clicks on the icon symbolizing the charging station and a new view is drawn on the screen. This view list all the available sockets, pointing out the following information for each one of them:

- The type of charging (AC/DC)
- The type of the socket (type 1, type 2, CCS, CHAdeMO, etc.)
- the charging speed denoted in kW and km/h (km gained per one hour of charge)
- The price for kWh
- The price for unlocking the socket

Scrolling down on the app, additional information regarding the station and the charging process are shown, like:

- accessibility to the station
- any additional fees set by the CPO, such as the cost per minute for parking during the charging process and the cost per minute for parking after finishing the charging (penalty for occupying the spot and not using it)
- Taxation information (VAT etc)

Being satisfied by the features offered by this station, Edward selects the appropriate socket for his EV and equipment (any additional charging adapter) and clicks the button to reserve the spot for the next X minutes.

Update profile details Jay is an electric vehicle enthusiast, who bought himself a new EV, in order to reduce the negative impact on the environment. Given this new purchase Jay needs to update its profile on the eMma in order to take advantage of the eMall service at its most. He logs in to its account on the mobile app and from the main page navigates to his profile. On the profile page are visible the personal information and the details about the EVs. Furthermore, there is the button that allows to update the profile and this is exactly what Jay is looking for. After pressing the button 'Update' there are different possibilities and Jay chooses the one that states 'Add new vehicle'. Now he has to fill up a form with the EV's details, such as type, capacity of the battery, supported power and current and so on. After double checking the form Jay presses the 'Ok' button and the page reloads showing again the profile page that now states among the other vehicles also the new one. Considering the eventuality of making mistakes in completing the form it is always possible to come back to the EV details and change any present field.

Visualize charging history It has been nearly 6 months since Hannah bought her first EV and now she has fully grasped how the whole ecosystem around it works. In the past few months Hannah has tried quite a few different charging stations to explore how each one is managed and organized. Having tried all these charging stations Hannah is curious to see how many charging stations she has visited, how frequently and how much she has paid for the charging. With this objective in mind Hannah opens the eMma application in her mobile phone and heads to the history section of it. This section is divided in two parts: in the top half the app shows the imminent charging booking that Hannah has reserved, if present. In the bottom half of the screen, the app shows a chronologically ordered list of all the charges processed through eMma. Each entry in the list shows the date in which the charging was done, where it was done, for how long, how many kWh were charged, the type of the socket used and how much did it cost distinguishing between cost for kWh and total cost.

Start a charging session Adeline usually goes to the supermarket nearer to her house because it has a charging station in the parking area. Most of the times she finds an available charging point so she charges her EV while she does the grocery. Once stopped the car in the available spot Adeline wants to start a charging session. She interacts with the charging point interface, visualizes the information about the available charge with the respective power and cost and inserts the code shown on the screen in the mobile app of the eMall, the eMma. Once initiated the session from the mobile phone, the data are sent to the system, and in particular to the CPMS part of the software that checks the correctness of the inserted code and registers the session related to the user. Then, the CPMS enables the flow of electricity in order to actualize the charging from the charging point. If during the check of the data and during the activation operations there are no errors the status of the charging point changes and the session is activated. Now, Adeline can insert the specific plug, compatible with her car, in the EV in order to actually start the charging, which if not stopped earlier will terminate when the battery is full.

A new user registers into eMma Michael, proud owner of an EV for 5 years, has decided to try this new charging app, eMma, that is promoting itself as a better alternative to manage in a smart way the charging process of an EV. Michael decides to give eMma a chance, downloads the app and immediately initiates the procedure to create a new account. The first phase of the registering process is straightforward; the usual information about name, family name, email and password are requested. After completing this first phase eMma prompts the user with a message asking him the consent to use his geographical location and to accept the terms of service. Micheal gladly accepts because he wants the app to show him the charging station nearest to him based on his location. After granting the consent a new page is presented to Michael. This time it is a form to be completed with the information about Michael's EVs specifications and his EV gear, like charging adapters and cables. Michael understands that this information is needed so the app can work in a smart way, showing him only the charging stations that have sockets compatible with Michael EVs connector or adapters. Finally the process to complete the registering begins; a form where Michael has to add his electronic payment details. After completing this last stage, the app opens and shows Michael a map of the area around him where the charging stations are highlighted with icons of bright colors.

Visualize the charging stations map Daisy is an unusual user of the eMall, that didn't registered an account. Anyway the system allows the possibility to use the application as a guest, but the functionalities are limited. Daisy is only interested in visualizing the charging stations nearby, so she opens the main page of the app in order to look at the map. The system retrieves, based on the location shared by the phone, the charging stations in the area and shows them on the map. Daisy can now explore the charging stations around clicking on them on the map, and she can see their rating with the relative reviews and can choose the service that better fits her needs. She can visualize the price and the available chargers with their type of connectors, but she is not able to book a charging session without an account. Once identified her preferred charging station Daisy closes the application, gets in her car and heads directly to charge her EV.

Manage the charging stations Nick is a CPO that on a typical day has to monitor the charging stations assigned to its department. After arriving to work and logging in the system with the company credentials Nick checks the list of charging stations and any new notification given by the CPMS part of the eMall about the DSOs decisions. He sees a warning regarding the recently deployed charging station in Rome and clicking on it the web application of the eMall shows a form with the various characteristics of the station. The parts that may have undergone a modification are highlighted in red and in this case the selection of the DSO has new options available and Nick clicks on it to explore the more convenient ones. He notices a change in one of the DSOs that now grants energy also through renewable resources, and given the green policy of the company he chooses this new kind of supply. Considering the price of 0.036/kWh provided by the DSO, in order to have a gain, according to the business modus operandi Nick sets the cost charging at 0.040/kWh. Once confirmed the DSO from which to acquire energy by looking carefully at the form he becomes aware of the fact that at the moment there are no EVD charging at the station and also sees that there are available batteries in which to store energy. One of the batteries is empty, so he selects it in order to store energy in it right away, until the full capacity C, given the off-peak moment. After all this operations Nick saves the changes and the eMall notifies him about the success of the procedure, that has an immediate effect on the system and his interaction with the world. Nick moves on to the next charging station of his list, checking up in similar way each one of the stations for which he is responsible.

2.2. Product functions

In this section, we briefly represent a list of the most important requirements of the `eMAll`, remainig on a high level of abstraction, since we will proceed to further discuss about them in much more detail in the next chapter.

2.2.1. Data collection and management

One of the main functionalities of the software is to store and manage different kinds of data coming from different sources:

1. The EVD using the eMma inserts into the system different kind of data. He inserts personal data, such as name, surname, and payment details; he also adds information about his EVs, like the maximum and minimum current supported, the connector type, the battery capacity and other relevant facts, like any additional EVSE he might own. The eMall allows the insertion of structured data and full-text elements that are subjected to checks in order to verify their correctness. The software maintains these data on the database in order to associate the bookings and the charging sessions to all registered EVDs, who can access all the functionalities of the system and are not subjected to the payment of a deposit every time they use a charging point
2. The DSO provides energy to the charging stations, and the information about

the DSO's supply is automatically collected by the CPMS subsystem of the eMall through interfaces that interact with the external systems. The CPMS acquires the information and saves it on the database in order for it to be visible to the CPO, and updates these data periodically. The collected data deriving from the DSO's are essential for the businesses, which make their supply choices depending on the price, the availability and the kind of acquired energy

3. The CPO manages the charging stations and their supply, visualizing the information kept by the software and making data-driven decisions for each one of the charging stations owned by the company. The CPO can see the parameters of each station and change them based on the new prices and types of energy, based on the chosen DSO to acquire from and based on the new politics of the CPO's company. All the data updates done by the CPO are received by the CPMS and collected by the system, so the managerial part of the service constantly produces data, about the charging stations. These data are stored and then used by the software to inform the EVDs of the charging stations details. The eMall also keeps data about the charging points and about the presence of batteries in each charging station, and these are useful information that need to be collected in order to allow to the CPOs to manage the service accurately

4. The charging station itself is an important source of data. Information about the charging points usage, both in terms of frequency throughout different periods of time (day, week, month) and usage time (for how long a certain socket has been used for each charging process) must be kept to enable the eMall system to conduct data analysis procedures (can give information about peak load hours) and empower the CPOs with relevant data for the business decision making process. Other information that can be tracked through the system include: client profiling (keep track of clients who visit the charging station), maintenance record, unused bookings profile

2.2.2. Communication and knowledge sharing

The eMall provides different tools to the EVD and to the CPO in order to take advantage of the service and obtain all the needed information from the system.. To be able to share this knowledge the subsystems of the software need to communicate among themselves and with the external entities. The offered tools are the following:

1. The eMma presents to the EVD all the information needed about the nearby charging stations. The application shows a map with the charging stations, and selecting a station the user can visualize further data, such as price, socket type, free charg-

ing points and other details. The eMma and the eMci are able to provide these information, because are part of the eMSP, which communicates with the CPMS to acquire the data about the charging stations

2. The web app available to the CPO, communicates with the CPMS part of the software getting the data about the electric supply offered by the DSOs, acquiring knowledge about the prices, the special offers and the available electric sources. The CPMS updates the information interacting periodically with the external service of the DSOs and shares the knowledge with all the CPOs, that manage the offered services

It is evident that among the functionalities of knowledge sharing and communication between the components involved, we also have as main features the following:

1. The eMma shows to the EVD the information about the nearby charging stations
2. The eMci shows to the EVD the data regarding the charging point in use
3. The CPMS gives to the CPO the knowledge of the DSOs changes and the last data saved for each charging station managed by the CPO

2.2.3. Main functionalities

Regarding the main functionalities that the EVD perceives, except for the ones already described, the most important ones remain:

1. The eMma allows to the EVD to book a charging point in a chosen time frame. Once the booking is completed from the app, the EVD receives a confirmation notification and the booking with an associated code is added to the user history of charges. The system saves the data related to the registered EVD and to the booking, so the eMSP maintains a copy of the code provided to the user, the data associated to the charging station and the chosen time frame. The effective charging service will be provided when the user will correctly insert the received code into the che eMci of the specific charging point. The eMall, after checking the code, activates a charging session with respect to the EVD, having in this way that the system provides the functionality of charging the EV in the time frame previously booked

2. The eMall gives, also, the possibility to charge without booking. In this case the EVD interacts with the eMma and the eMci. From the two interfaces the data arrive to the eMSP, which creates the charging session and allows the user to use the service

2.3. User characteristics

The eMall has three main user classes:

1. **Unregistered EVD**: An EVD can register to the eMall or use the service without registration. In order to register, the user has to introduce personal data and the details of the EVs, so he creates a profile with an associated name and a password. By creating a profile is possible to take advantage of all the features provided by the service, having some privileges, but the eMall can also be used without any registration. The eMma can be downloaded on the phone and used as a 'guest' and in this case is still possible to visualize the map with all the nearby stations and their information. It is also possible to book a charging session from the application, but is necessary at least the insertion of the payment details and the payment of a deposit in advance in order to use this functionality. Even in the case of charging the EV without any booking, the unregistered EVD has to give a deposit before starting the charging session. Furthermore, the EVD without a profile doesn't have the history of charges, so there are some limitations in using the system

2. **Registered EVD**: An EVD is registered if creates an account inserting personal data and EVs details. The registered EVD interacts with the eMma and the eMci in order to use the main functionalities of the system: to book a charging session, to charge the EV without a booking, to visualize the nearby charging stations and to visualize and modify the personal profile and history. The EVD, registered or unregistered, can be unfamiliar with the use of mobile applications, so the software needs to be user-friendly in order to guarantee a good service in all its aspects

3. **CPO**: A company that supplies the service is identified with the employees or the existing software, that interacts with the eMall system. In the interaction the part of the company is called the CPO and manages the charging stations provided by the company itself. The CPO is able to visualize all the stations and the respective charging points and can change the supply parameters, modifying the price of the charge, the storage of energy, the DSOs from which to acquire electricity and other details. All these changes are possible given the interaction of the CPO with the CPMS part of the eMall, which has the necessary knowledge, that is communicated to the company in order to administer the stations and offer the service properly

2.4. Assumptions, dependencies and constraints

Assumptions	Description
D1	The EVD has internet connection
D2	The EVD has a mobile phone with an integrated GPS module
D3	The EVD has the mobile application of the eMSP installed on his mobile phone
D4	The CPOs share the location of the charging stations to the eMall through APIs
D5	The end user payment from the mobile app is handled by external APIs.
D6	The EVD that creates an account inserts the personal data and the correct payment details during registration
D7	The non registered EVD inserts the EVs specifications and payment details during the booking phase
D8	The DSOs use smart meters to detect interruptions and restore the supply of energy
D9	The CPO uses company credentials to access the web application of the eMall

Table 2.1: Assumptions

3 | Specific requirements

3.1. External Interface Requirements

3.1.1. User Interfaces

In this subsection we provide some mockups that show an example of some possible user interface, one for the mobile app which will be available to the users and one for the web app available to the businesses, that offer the charging service.

EVD interaction with the mobile app of the eMall The EVD needs to download the mobile app on his cellphone in order to interact with the eMall and take advantage of its functionalities. The Graphical User Interface (GUI) of the application is thought as an user-friendly interface, to facilitate everyone in using the service. In this first mockup we see the initial page of the system, shown to the user when opening the application.

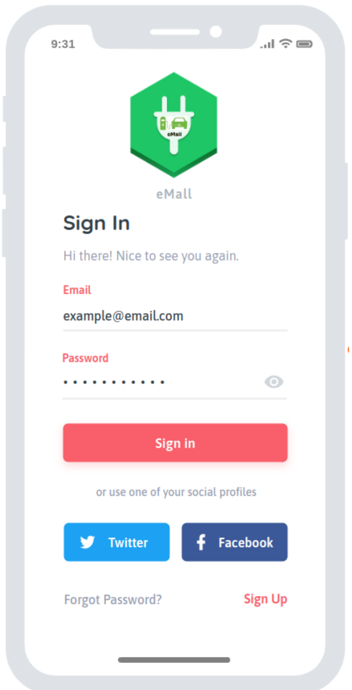

Figure 3.1: Wireframe of the page that allows to log in from the eMma

In the following mockups we represent an example of the signing up procedure, showing the data required by the eMma in order to complete the creation of an account.

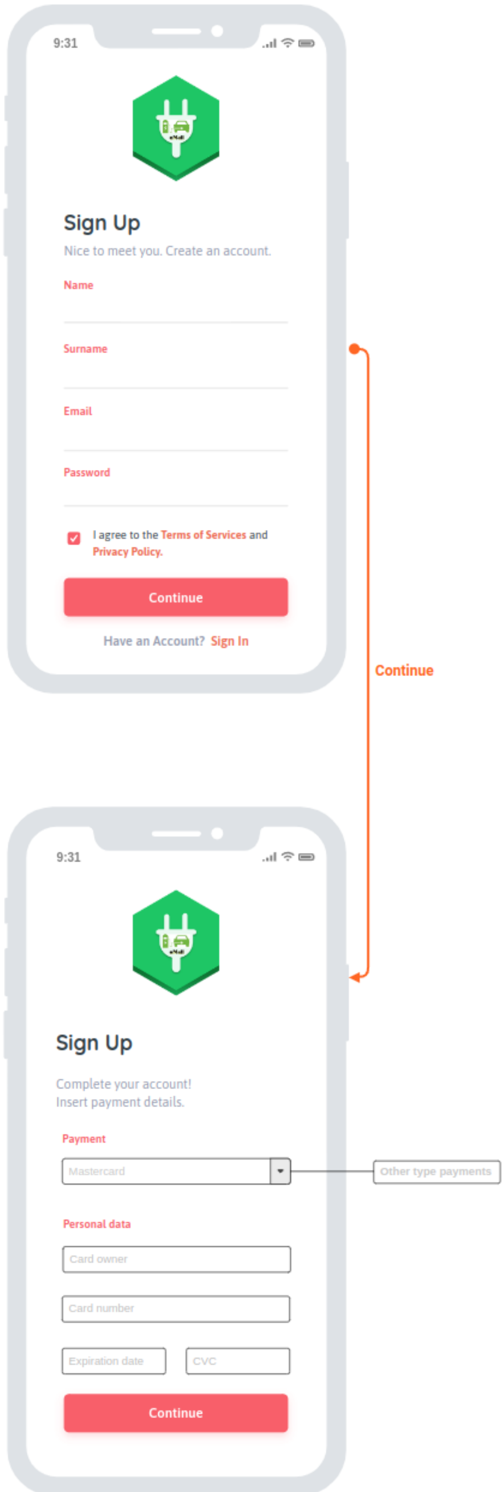

Figure 3.2: Wireframe of the signing up process that allows to register from the eMma

CPO interaction with the managerial web app of the eMall

3.1.2. Hardware Interfaces

3.1.3. Software Interfaces

3.1.4. Communication Interfaces

3.2. Functional Requirements

3.3. Performance Requirements

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

Activity	**Time spent**
Organization	5h
Understanding the problem	10h
Introduction to the problem	10h
Scenarios and overall description	10h
Functional and non-functional requirements	h
Formal analysis using Alloy	h
Total time spent	h

Table 5.1: The time Bianca Savoiu has spent working on this project

Activity	**Time spent**
Organization	5h
Understanding the problem	h
Introduction to the problem	h
Scenarios and overall description	h
Functional and non-functional requirements	h
Formal analysis using Alloy	h
Total time spent	h

Table 5.2: The time Fabio Lusha has spent working on this project

6 | References

Bibliography

[1] C. Larman. *Applying UML and Patterns*. Prentice Hall PTR, 2005.

List of Figures

List of Tables