Politecnico di Milano
School of Industrial and Information Engineering
Master of Science in Computer Science and Engineering

Software Engineering 2 Project

eMall - CPMS system

Requirement Analysis and Specification Document

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Contents

List of Figures

1 Introduction

1.1 Purpose

The purpose of this document is to analyze and define the goals and requirements of the Charging Point Management System (CPMS), the IT structure capable of managing a car charging station.

1.1.1 Goals

G1	Allow eMSP to start and end a charging session
G2	Allow eMSP to be notified when the charging process is completed
G3	Allow CPO to have information about the internal status of a charging stations
G4	Allow eMSPs to have information about the current tariffs
G5	Allow eMSPs to have information about the position of the charging stations
G6	Allow eMSPs to have information about the status of the car charging process
G7	Allow CPOs to manually decide the current energy price
G8	Allow CPOs to manually decide from witch DSO acquire energy
G9	Allow CPOs to manually decide whether to use or store energy inside batteries
G10	Allow CPOs to have information about the internal status of a charging stations
G11	Dynamically decide the energy source to use

1.2 Scope

Each charging station managed by the Charging Point Operators (CPO) has an IT infrastructure called Charge Point Management System (CPMS). Through this application, administrators are able to manage the various charging stations such as the selection of the DSO and the use of the batteries present in the stations. The CPMS must be able to manage the station,deciding independently the most optimal energy management policy. The CPMS is able to connect the charging station with the rest of the e-Charging ecosystem, allowing an interaction with the user and with the various energy suppliers (Distribution System Operators (DSO)).

1.2.1 World Phenomena

WP1	eMSP wants to start a charging session
WP2	eMSP wants to know the rates offered by the various CPMS
WP3	eMSP wants to book a charging session at a specific charging point
WP4	User disconnects the Electric Vehicle from the Charging Slot
WP5	CPO starts the maintenance of a Charging Slot
WP6	CPO completes the maintenance of a Charging Slot
WP7	CPO decides to check the internal status of a charging station
WP8	CPO decides to set up an energy management policy of one charging point
WP9	CPO decides to change the price of tariffs
WP10	CPO decides to change from which DSO acquire energy
WP11	DSO provide energy to the charging point

1.2.2 Shared Phenomena

SP1	eMSPs request information about the charging points
SP2	eMSPs books a charging session
SP3	eMSPs receives information about the state of the charging session

Charging point side

SP4	System authenticate the charging session
SP5	The system activates a charging socket of an charging slot, making it available
SP6	The system deactivates a charging socket of an charging slot
SP7	charging slot sends to the system information about the charging status of the car
SP8	charging slot communicates diagnostic information to the system

CPO side

SP9	The system shows the current energy management settings to the CPO
SP10	CPO login into the system and change the energy management settings
SP13	CPO login into the system and change the energy price
SP14	CPO login into the system and view information about the internal status of the system
SP14	System notifies the CPO of a component malfunction

1.3 Definitions, Acronyms, Abbreviations

1.3.1 Definitions

Connector Charging Socket	Physical connector that allow to transfer energy to the connected vehicle
Charging slot	Physical device with multiple Connectors that can charge electric vehicles. NOTE: from OCPI definitions a Charging Slot can have up to one connector active at any time (i.e. can charge only one Vehicle at any time)
Charging Point	Physical structure composed by multiple Charging Slots
Maintenance of a charging slot	Activity/activities that results in a momentary unavailability of the charging slot
Charging session	period of time when the vehicle is connected to a charging plug for charging
Booking period	period of time between the booking of a charging session and the beginning of the charging session
Internal status	The amount of energy stored in the batteries, if any, the quantity of vehicles currently being charged, and the current energy management settings.
External status	Number of charging sockets available, their type such as slow/-fast/rapid, their cost, and, if all sockets of a certain type are occupied, the estimated amount of time until the first socket of that type is freed.

1.3.2 Acronyms

eMSP	e-Mobility Service Provider
CP	Charge Point / Charging Point
CS	Charge Slot / EVSE
CPO	Charging Point Operator
CPMS	Charging Point Management System
OCPI	Open Charge Point Interface
EV	Electric Vehicle
OCPP	Open Charge Point Protocol
DSO	Distribution System Operators

1.4 Revision History

- v1.0 - 10 December 2022
- v1.1 - 23 December 2022
- v1.2 - 6 January 2023

1.5 Related Documents

OCPI specifications document
OCPP specifications document

1.6 Document structure

The document is structured in six sections:

1. Problem introduction, associated goals of the project. In this section you can also find the scope of the project, the various phenomena occurring and the definitions and abbreviations used in this document.

2. The second section contains a overview of the system, the details about the main functionalities. Class diagrams, state-charts and domain assumptions are used to introduce the various scenarios.

3. In this section are specified the different requirements of the system, the various use cases and the mapping between functional requirements and the goals of the system.

4. Alloy is used to conduct the formal analysis of the system.

5. Total effort

6. References used

2 Overall description

2.1 Product perspective

2.1.1 Scenarios

1. **CPO wants to start using the platform**

   Antony, the owner of two charging stations, wants to optimize their use and join the e-Charging ecosystem. He contacts customer service and arranges for the installation of a CMPS on a cloud server. Antony then connects his stations to the internet, connecting each charging slot. With the assistance of technicians, he inputs all the necessary information into the system to ensure it can effectively manage his two charging stations. After the installation is completed, Antony accesses the CPMS portal and offers a discount on the prices he charges to celebrate the new system. The eMSP network is notified of the presence of the new CPMS. The DSOs located at the various stations are also connected, allowing for dynamic selection of the energy source

2. **CPO wants to change the price of the energy sold**

   Alice is the administrator of a charging station and has decided to increase the price of energy. Alice opens the internet portal of her CPMS via a browser. By entering the credentials, Alice accesses the interface concerning the proposed price. After a careful analysis, Alice changes the price and presses the "Save Changes" button.

3. **CPO wants to disable a charging socket to perform maintenance**

   Fabio is a CPO and has to carry out routine checks on the correct functioning of a charging socket. Fabio opens the internet portal of her CPMS via a browser. By entering the credentials, Fabio accesses the booking interface. Fabio selects an available time slot and presses the "Maintenance" button.

4. **eMSP wants to start a charge at the CP**
   eMSP wants to start a new charging session, but without having a reservation at the indicated charging point. Then it sent an immediate booking request for a charging slot to the system. The system verifies that there is availability in that particular station. Since

there is availability, the system adds the session to the schedule and sends a confirmation message to the eMSP.

5. **eMSP wants to be notified at the end of the charge**

   The eMSP wants to receive information regarding the status of the current charging session identified by a booking_id. The system therefore every time it receives information on the status of the session from the charging slot, notifies the eMSP about the status.

2.1.2 Class Diagram

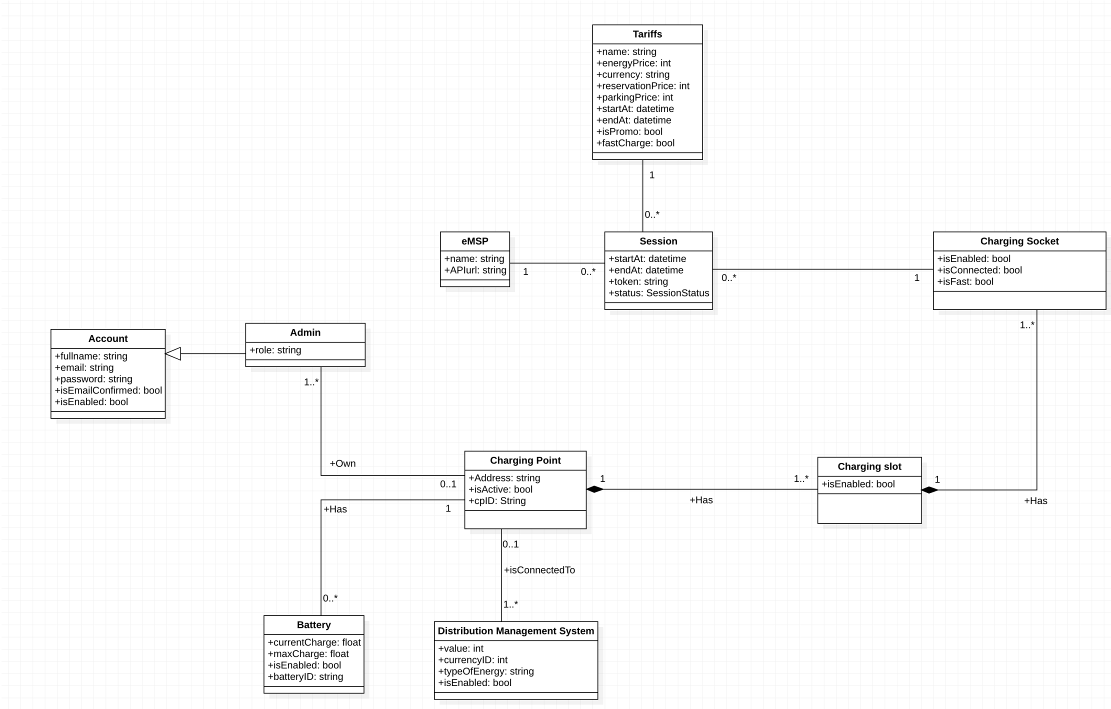

Figure 2.1: Class diagram of the CPMS system for eMall

2.1.3 State charts

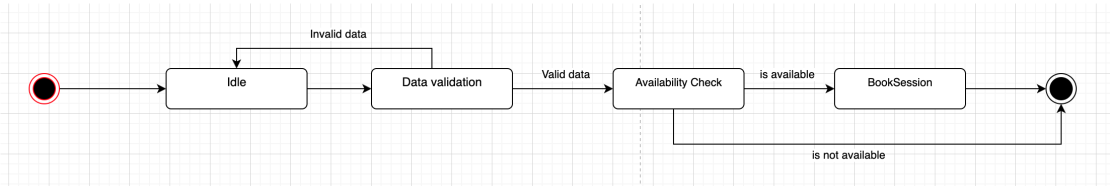

Figure 2.2: State diagram for Booking

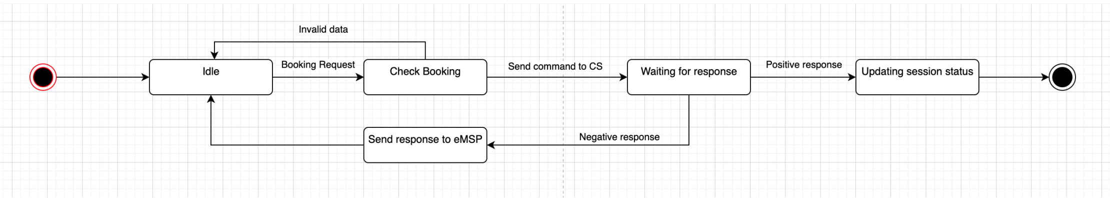

Figure 2.3: State diagram for a Charging Session

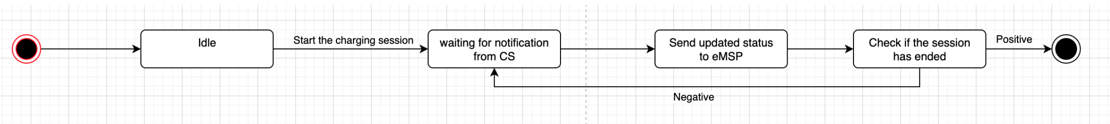

Figure 2.4: State diagram for monitor session status

2.2 Product functions

In this section the main functionalities of the CPMS is presented and described in more detail.

- As OCPI enables a very complex pricing system, to keep the scope of the project simple, the system will use only the per-KW price (also called energy based price), with differentiation between fast charging and non-fast charging. Time limited promotions are also allowed.The prices are synced by the CPMSs via the PUSH interface defined in the OCPI protocol. (i.e. at any time, each CPMS can define only two active prices: standard and fast-charging).
- Another limitation that we need to impose to reduce the complexity is the various connector types. We define only two generic types of connector: standard and fast-charging, each type has its own pricing defined by the CPMS.

2.2.1 Dynamically decide the energy source to use

The dynamic management of the needed energy resources is one of the CPMS's main responsibilities. It should also be able to dynamically decide from which DSO to acquire energy based on the current price and energy source mix, and decide whether to store or use energy from the station's batteries.

2.2.2 Communicate information to the various eMSPs

The system must be able to communicate via the OCPI protocol with the various eMSPs that make port on the network. Through this protocol, the two actors will be able to communicate information such as: position of the charging stations managed by the CPO, rates offered, availability for reservations, type of charging available.

2.2.3 CPOs, station monitoring and management

It must be possible to monitor and display information such as: tariffs offered, current cost of energy purchased from DSOs, battery status, reservation schedules. Furthermore, the admin must be able, through a dedicated portal, to make changes and decisions on the management of the station.

2.2.4 Manage the reservations schedule

The system should be able to manage and keep track of the reservations that are made by the various eMSPs. The system must be able to handle the modification, if possible, or cancellation of reservations.

2.2.5 Interaction with DSOs

The system must be able to communicate with the various Distribution Management Systems (DSOs). The system must be able to request information such as: energy price, energy type. It must also be able to request connection and supply of energy from each DSO.

2.2.6 Communication with the charging slots

The system should be able to communicate with the charging slots present in each charging point. communication must take place via the OCPP protocol. The exchange of information such as: diagnostic data, charging status, activation of the charging socket must take place through this protocol.

2.3 User characteristics

We can identify a CPO administrator as the only user of the CPMS system. For the purpose of the project we assume that situations in which the CPO administrator is not present or registered are not allowed.

1. **CPO Administrators**
   The CPO will utilize the CPMS to oversee their charging stations and manually address tasks such as selecting which DSO to obtain energy from or establishing special offers for charging stations.

2. **Maintainer**
   A person responsible for maintaining and repairing all parts of the charging station.

2.4 Assumptions, dependencies and constraints

2.4.1 Assumptions

D1	There is a system admin that does the initial setup of the system and manages it
D2	The system admin adds the necessary information about charging point, slots to the database
D3	DSOs are connected and entered into the system by the admin during the initial set up
D4	Users always complete their booked charging session
D5	Payments to DSOs are handled externally to the system

3 Specific Requirements

3.1 Use Case Diagrams

Here are displayed the most important use case diagrams for the various actors.

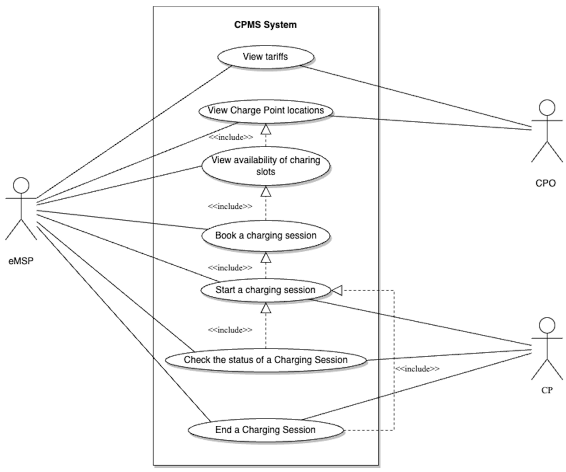

Figure 3.1: Use case diagram for eMSP

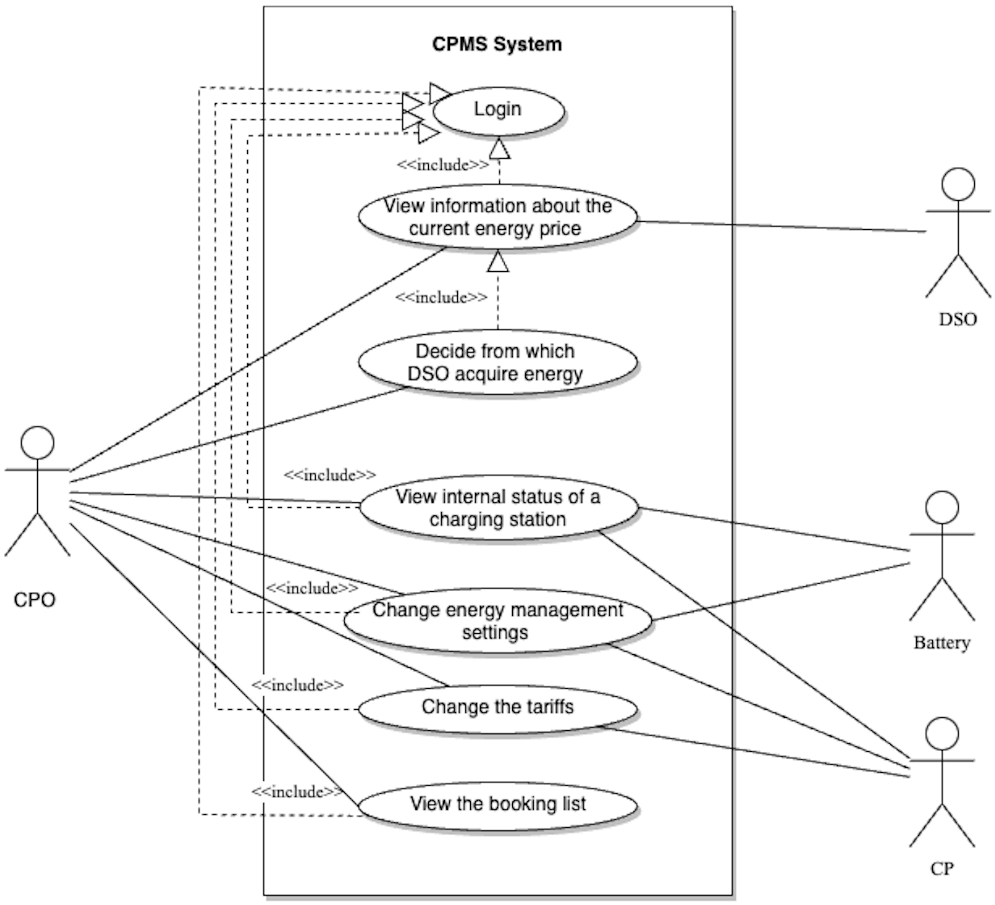

Figure 3.2: Use case diagram for an CPO

3.2 Use Cases

1. **CPO login**

Actor	CPO admin
Entry conditions	The CPO is registered into the system bus has to log in
Event flow	1. The admin open the web portal of the CPMS 2. The admin taps the "LogIn" button 3. The admin fills up the form 4. The system validates the data and grants access to the admin 5. The system redirect the admin to the main page
Exit condition	The admin is logged in
Exceptions	1. The form data are incomplete or not valid 2. The system cannot process the data

2. **View information about energy price**

Actor	CPO admin, DSOs
Entry conditions	The admin is logged in
Event flow	1. The admin taps on the "View energy prices" button 2. The system request to DSOs informations 3. The system shows the list of prices proposed by the various DSOs, also indicating the type of energy
Exit condition	The admin goes yo another section or close the page
Exceptions	1. The system is unavailable 2. Some or all of the DSOs are unavailable or unreachable

3. **CPO Change energy management settings**

Actor	CPO admin
Entry conditions	The admin is logged in
Event flow	1. The admin select the charging station from the list 2. The admin taps on the "Energy management" button 3. The system shows a page with all the information on the current energy management 4. The admin taps on the "Modify" button 5. The system shows a page with all the parameters that the CPO can modify 6. The admin modifies the parameters 7. The admin taps on the "Save" button
Exit condition	The admin goes yo another section or close the page
Exceptions	1. The system is unavailable 2. Some or all of the DSOs are unavailable or unreachable

4. **Displays information about the internal status of a charging station**

Actor	CPO admin
Entry conditions	The admin is logged in
Event flow	1. The admin select the charging station from the list 2. The admin taps on the "System monitor" button 3. The system shows a page with all the information about the charging station status
Exit condition	The admin goes yo another section or close the page
Exceptions	1. The system is unavailable

5. **Start a Charging session**

Actor	eMSP, Charging point
Entry conditions	The charging slot has been booked
Event flow	1. The system receives the command from the eMSP 2. The system verifies the validity of the reservation 3. The system sends the command to the charging slot 4. The system sends the confirmation to the eMSP
Exit condition	eMSP receive a response
Exceptions	1. The charging slot is unreachable 2. The system does not confirm the reservation 3. The charging slot does not confirm activation

6. **End a charging session**

Actor	eMSP, CS
Entry conditions	There is a active session
Event flow	1. The system receives the request to end the session from the eMSP 2. The system sends the request to end the session to the CS 3. The system receives the end session confirmation from the CS 4. The system send the confirm to the eMSP
Exit condition	eMSP receives a response
Exceptions	1. The CS is unreachable 2. The CS cannot end the session 3. eMSP cannot receive the response

7. **Update the state of the charging session**

Actor	eMSP, CS
Entry conditions	There is a active session
Event flow	1. The system receives information about the status of the charging session from the CS 2. The system sends information about the status of the charging session to the eMSP
Exit condition	eMSP receives information about the status of the charging session
Exceptions	1. eMSP is unreachable 2. The CS cannot reach the system

3.3 Sequence Diagrams

Here are presented the sequence diagrams for the most important use cases.Only the "success" flow is displayed, every exception in the communication flow results in an error message displayed to the log file and a request retry.

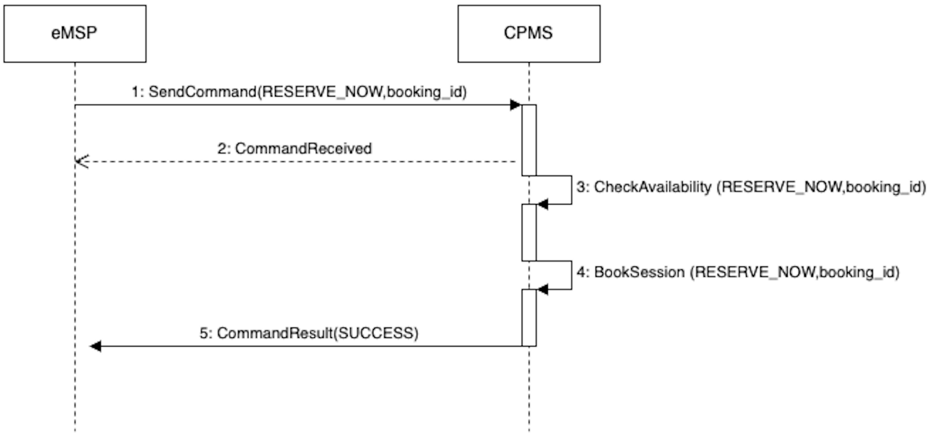

Figure 3.3: Sequence diagram for the booking process of a new charging session

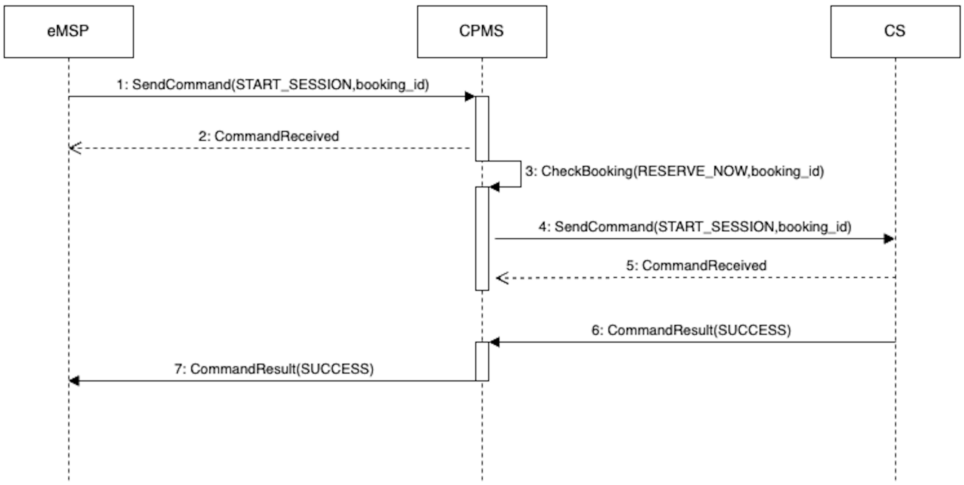

Figure 3.4: Sequence diagram for the starting of a charging session

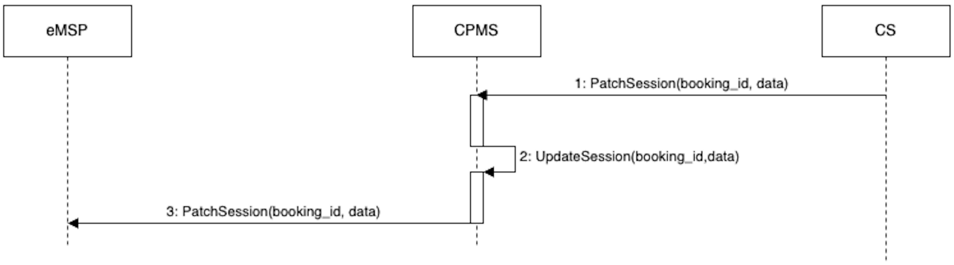

Figure 3.5: Sequence diagram for the notification of a charging session state

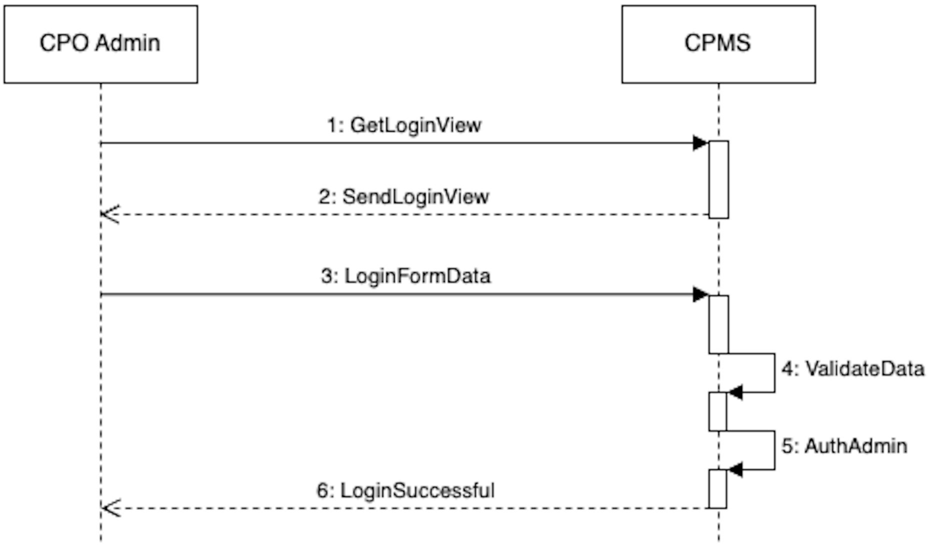

Figure 3.6: Sequence diagram for the change of energy management settings

3.4 Functional Requirements

The system should:

Requirement	Description
R1	Allow to book a charging session on a specific CS
R2	Allow to start a charging session on a specific CS
R3	Allow to stop a charging session on a specific CS
R4	Forward information about the state of a charging session to the eMSP
R5	Allow Login for CPO
R6	Allow to view information about the internal status of a charging station
R7	Forward of the offered tariffs
R8	Allow CPO to set or change tariffs
R9	Allow CPO to enter static information about charging stations
R10	Forward information about the location of charging stations
R11	Allow CPOs to view information about the external status of a charging station
R12	Allow CPOs to change the settings and management settings of the charging station
R13	Dynamically decide the tariffs offered

3.4.1 Requirements mapping on Goals

Goal	Requirements
G1	R1, R2, R3
G2	R1, R2, R3, R4,
G3	R5, R6
G4	R5, R7, R8
G5	R9, R10
G6	R10
G7	R5, R12
G8	R5, R12
G9	R5, R12
G10	R11

3.5 Performance Requirements

As most of the Charge Points are located in the city centre, where internet connectivity is usually optimal and at high speed, the system does not have special requirements for performances related to bandwidth usage. Also, no particular usage spikes are expected at any moment, so server load should be directly connected to the number of users and Charge Points covered by the system.

3.6 Design Constraints

3.6.1 Standards compliance

For the legal aspect it is necessary to follow the requirements of the GDPR regarding the management of sensitive data of users and CPOs. While to allow interconnection with the different eMSPs and CPs, it is necessary to follow the OCPI and OCPP standards in the implementation of communication protocols and data structures.

3.6.2 Hardware limitations

No particular hardware are required to use the System.

3.7 Non-functional Requirements

NFR1	Reliability impacts the system usage and the related business, to keep it as high as possible, fall back servers shall be considered while designing the infrastructure.
NFR2	Availability also has a huge impact but as this is not a sensible service that needs to be up and running at all time, a good compromise with cost effectiveness can be considered.
NFR3	The basic security standard "defacto" measurements should be followed, SSL and HTTPS should be enough to offer both security and ease to use.

3.8 External Interface Requirements

3.8.1 User Interfaces

The CPO's user interface can be accessed via a web portal that can be used on any device with an internet connection and a web browser.

3.8.2 Hardware interfaces

There are no hardware interfaces

3.8.3 Communication interfaces

As the system needs to communicate with multiple actors, the following communication interfaces are required:

1. **CPMS communication:**
   To share data with the various eMSPs, an active, low-latency internet connection is needed. Also is required that the eMSP follows the OCPI protocol.

2. **CS communication:**
   To share data with the various CPs, an active, low-latency internet connection is needed. Also is required that the eMSP follows the OCPP protocol.

4 Formal analysis

4.1 Alloy formal analysis

In this section is described a formal analysis written using Alloy. The purpose of the analysis is to highlight the key model relationships and the main constraints of the system.

The model has been built following the class diagram, the included code contains all the models and the relationships, and it shows that the resulting system is feasible and useful and it justifies our modelling decisions.

In the following sections you will find the code used to run the analysis and some of the world that the Alloy tools generated from our definitions.

4.2 Alloy code

```
//abstract sig String {}
abstract sig Bool {}
one sig TRUE extends Bool {}
one sig FALSE extends Bool {}


sig ConnectorType {}
sig Device {} {
   (one u: User |this in u.devices) and -- device needs a user
   (no disj u, u': User |this in u.devices & u'.devices) -- no device can be owned by
       ↪ multiple users
}

sig LicensePlate {} {
   (one v: Vehicle |v.licensePlate =this) -- licence is used only as string here so
       ↪ cannot exists without a vehicle
}
sig Vehicle {
   licensePlate: one LicensePlate,
   connector: one ConnectorType
} {
   (one u: User |this in u.vehicles) and -- vehicle needs a user
   (no disj u, u': User |this in u.vehicles & u'.vehicles) -- no vehicle can be owned by
       ↪ multiple users
}

sig User {
   devices: set Device,
   vehicles: set Vehicle,
   bookings: set Booking
} {
   #devices >0 and #vehicles >0
}


sig CPMS {
   chargingPoints: set ChargingPoint,
   tariffs: set Tariff,
} {
   (#chargingPoints) >0 and
   (#tariffs >0) and
   (one u: CPO |this in u.own) and
   (no disj u, u': CPO |this in u.own & u'.own)
}

sig CPO{
   own: set CPMS
}{
   #own >0
```

```
}

sig ChargingSocket {
   isFast: one Bool,
   connectorType: one ConnectorType
} {
   (one slot: ChargingSlot |this in slot.sockets) and -- sockets needs to have one slot
       ↪ connected
   (no disj s, s': ChargingSlot |this in s.sockets & s'.sockets) -- no multiple slots
       ↪ for the same socket
}

sig ChargingSlot {
   sockets: set ChargingSocket
} {
   (one cp: ChargingPoint |this in cp.chargingSlots) and -- charging slot needs to be in
       ↪ a charging point
   (no disj cp, cp': ChargingPoint |this in cp.chargingSlots & cp'.chargingSlots) and --
       ↪ a charging slot cannot be in multiple charging points
   (#sockets >0)
}

sig DSO {}{
   (one c: ChargingPoint |this in c.dso)
}

sig ChargingPoint {
   chargingSlots: set ChargingSlot,
   dso: set DSO
} {
    (one cpms: CPMS |this in cpms.chargingPoints) and -- charging point needs a CPMS
    (no disj cpms, cpms': CPMS |this in cpms.chargingPoints & cpms'.chargingPoints) and
        ↪ -- charging point cannot have multiple CPMS
    (#chargingSlots >0) and
    (#dso >0)
}

sig Tariff {
   startAt: one Int,
   fastCharge: one Bool,
} {
   (startAt >0) and -- dates as timestamps so they need to be > 0
   (one cpms: CPMS |this in cpms.tariffs) and -- tariff needs a CPMS
   (no disj c, c': CPMS |this in c.tariffs & c'.tariffs) -- no tariff can be used for
       ↪ multiple CPMS
}

sig BookingStatus {

}

sig Booking {
   status: one BookingStatus,
```

```
   vehicle: one Vehicle,
   slot: one ChargingSlot,
} {
   (one user: User |this in user.bookings and vehicle in user.vehicles) and -- booking
       ↪ needs a user and vehicle must be owned by the same user
   (no disj u, u': User |this in u.bookings & u'.bookings)
}


/** ---- FACTS ---- */
fact noDifferentVehiclesWithSameLicensePlate {
   no disj v, v': Vehicle |
      v.licensePlate =v'.licensePlate
}


fact noMultiplePricingActiveAtTheSameTimeForTheSameCPMS {
   all cpms: CPMS |(
      no disj t, t': cpms.tariffs |(
         t.startAt =t'.startAt and
         t.fastCharge =t'.fastCharge
      )
   )
}


/** ---- ASSERTIONS ---- */
assert deviceHasOneUser {
   no d: Device, u, u': User |
      u ≠u' and
      d in u.devices and d in u'.devices
   and
   all d: Device |
      one u: User |d in u.devices
}

check deviceHasOneUser


assert cpmsHasOneCPO {
   no d: CPMS, u, u': CPO |
      u ≠u' and
      d in u.own and d in u'.own
   and
   all d: CPMS |
      one u: CPO| d in u.own
}

check cpmsHasOneCPO

assert noMultiplePricingActiveAtTheSameTimeForTheSameCPMS {
   no disj t, t': Tariff |(
      t.~tariffs =t'.~tariffs and t.startAt =t'.startAt and t.fastCharge =t'.fastCharge
```

```
   )
}

check noMultiplePricingActiveAtTheSameTimeForTheSameCPMS

/** ---- PREDICATES ---- */

pred noCPMSInsertedWorld {
   #User >0 and
   #CPMS =0
}
run noCPMSInsertedWorld for 5

run world1 for 5

pred world2 {
   #CPO >1 and
   #User >1 and
   #CPMS >1 and
   #Booking >1 and
   #DSO >1 and
   (some cpms: CPMS |#cpms.tariffs >1)
}
run world2 for 5
```

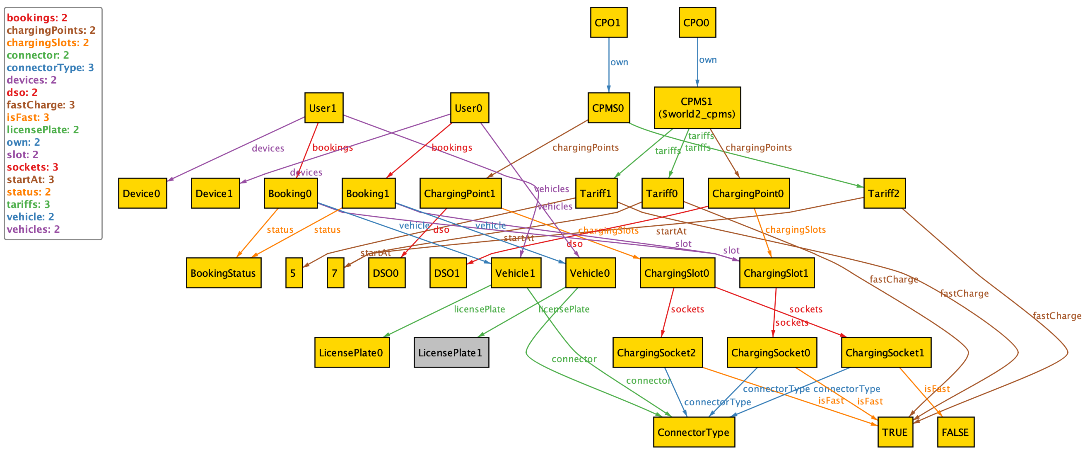

Figure 4.1: World generated by Alloy (world2)

14 lines (14 sloc) 243 Bytes

5 Effort spent

Task	Time spent
Introduction	7 h
Overall description	11 h
Specific requirements	20 h
Alloy/Formal analysis	3 h
Document revision	2 h