SMART GRID SERVICES DESIGN

D4.2- Smart grid services design

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Abstract

This report presents the design of the smart charging services to be offered by the USER-CHI project through the smart charging tool (SMAC) implementation. Smart charging functionalities are conceived to provide benefits to EV drivers, giving them the possibility to specify their charging preferences such as the required state of charge (SoC) of the EV battery within a certain period. Besides, with a system that provides smart charging operations, Charge Point Operators (CPOs) will be able to manage efficiently the power provided to the electric vehicles in their charging stations, as well as performing vehicle to grid (V2G) operations when needed. The hardware and software components, their communication and the interaction with the actors involved in the smart charging ecosystem are detailed in this deliverable.

Keywords

Smart charging, protocols, roaming, vehicle to grid, smart charging inputs, EV driver, charge point operator, dynamic load management, interoperability, charging profile.

Copyright statement

Executive summary

The USER-CHI deliverable D4.2 "Smart grid services design" summarises the results of task T4.2, whose aim is the definition and specification of the smart charging tool, SMAC.

The design of the smart charging services to be offered by SMAC is related to the restrictions and requirements defined by the consortium members in previous tasks. From this information, it has been possible to identify the smart charging functionalities, as well as the workflow between the smart charging service provider with the final users and with other USER-CHI actors and systems.

The information exchanged among the different SMAC components will be crucial for the calculation of the smart charging profiles, which means the target power supplied at each moment to the charging point, therefore, to the vehicle.

All aspects involved in this report set the foundations for the development of the smart charging solution provided by the USER-CHI project, the SMAC tool.

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1. Introduction

1.1 Purpose of the document

The purpose of this deliverable is to document the work carried out in Task T4.2 "Smart grid services design". This task defines the high-level architecture of the Smart charging tool (SMAC), the functionalities provided and the services with their respective components offered by the product backend and final user devices.

1.2 Scope of the document

D4.2 provides the identification of the set of use cases of the product which let the specification of SMAC functionalities grouped in different functional blocks, as well the high-level design of the services to be provided by the system. All descriptions are textual and conceptual, oriented to identify the aspects to be covered in the exchange of information and the behaviour of the services. The design provided in this document could be seen as the starting point for the further implementation of the smart charging tool.

1.3 Structure of the document

Apart from this introductory section, the current document is structured as follows:

The first section aims to connect the smart grid services design task with the related tasks presented in other work packages.

Following that section, the document is focused on describing the functionalities and capabilities that compose a smart charging system, the identification of the different functional elements of a smart charging tool and the specification of the set of use cases representing the flow of interactions between final users and the components of the SMAC ecosystem.

Chapter 4 presents the components and services of the SMAC tool, the workflow and how it communicates either internally, with end-user devices or with third party services.

Finally, the document ends with a brief summary and the exposition of the main conclusions that can be extracted from the whole document.

2. Connection to other tasks

2.1 Usage scenarios, T1.2

Task T1.2 is focused on integrating the requirements and types of solutions demanded by the end-users and the five demo sites involved in the project. The usage scenarios set the baseline for the design and implementation of SMAC product and therefore act as a reference for the demonstration. The result of this task, included in Excerpt of D1.2: SMAC Usage Scenarios of this document, can be considered the starting point of the definition of the smart charging tool use cases, services and final users.

2.2 Technical and legal requirements, T1.3

This task is focused on collecting the requirements that USER-CHI solutions should consider when developing the products and the standards and normative restrictions that USER-CHI solutions must accomplish in all of the five partner countries and a selected set of at least 5 other relevant EU countries. A result of T1.3 is to know the different technical requirements that must be taken into account for the design and development of USER-CHI products. T1.3 concluded while the smart charging tool was still been designed. Consequently, some relevant technical aspects and requirements could not have been detailed in T1.3, therefore, they are presented in this report. The results of T1.3 are included in this document in Excerpt of D1.3: SMAC Legal and Technical Requirements.

2.3 Design and specification of interoperability and roaming services, T3.1

Task T3.1 describes the different services the INCAR platform aims to offer. Between these sets of services, their interoperability and roaming services are conceived to involve the charging stations presented in the USER-CHI project in order to make them available for any EV driver and managing the recharges [1]. Taking into account that smart charging operations shall be performed in the charging stations managed by INCAR, it has been considered suitable to design SMAC as a tool that provides smart charging services to the charging stations linked to INCAR. This means that the smart charging services offered by SMAC in certain charging station connected to INCAR will be available not only to certain users but to anybody using the USER-CHI app. In the following chapters, it will be detailed how both systems will be able to communicate and execute the dynamic load management of charging transactions.

3. Smart grid services functional definition

The purpose of this chapter is to document the work carried out during the definition and design of SMAC functionalities. With this objective, the first subsection defines a brief introduction of the definition and benefits of smart charging services provided by SMAC. The following chapter defines the guiding use cases for the smart charging services and for the related services, and final user devices that will be employed. The use cases specified are the main input for the specification of the whole set of SMAC functionalities and services. After that section, the identified functional blocks of the platform are presented.

3.1 Smart charging services overview

This section provides an introduction to the smart charging concepts and benefits, as well as smart charging tool main functionalities and services.

Smart electric vehicles charging or dynamic load management refers to a system where a charger, which is charging an EV, communicates with the car and the charge point operator, sending them important data so they can optimise the charging. As opposed to traditional (or dumb) charging devices, smart charging allows the charging operator to monitor, restrict and manage remotely how much energy deliver to any plugged-in EV in their charging stations, optimizing energy costs. The amount of power supplied can vary depending on several factors, such as the number of EV charging at the same time, the charging stations maximum power capacity, or the energy tariff subscribed.

Bidirectional charging or V2G, on the other hand, describes a system in which the driver of an all-electric or plug-in hybrid vehicle can sell energy to the electricity grid when the car is connected to the grid and is not charging. Alternatively, when the car batteries need to be recharged, the flow will be reversed and the electricity will flow from the grid to the vehicle. This means that the EV battery works as a bidirectional device with respect to the grid. This kind of operations, also involved in smart charging services, could help to boost the grid's energy supply at times of peak demand.

These smart charging features provide benefits to different stakeholders involved in electromobility scenario:

- For businesses with charging points, the management of their charging services will be a key element to benefit from the increasing adoption of EVs. On the economic side, smart charging enables businesses with charging points to set limits on power consumption, which ensures the business does not exceed their location´s power limit, avoiding costly demand charges in the process. However, the most important benefit of smart charging is that the CPOs can provide an improved and tailored service to their customers, being able to meet the particular customer´s needs (such as desired energy and time available for charging) while reducing its operational costs. CPOs can operate the different charging stations according to the specific dynamic demand, energy prices, and renewable local energy production in combination with dynamic tariffs, to manage the offer and the demand of the charging stations with the final aim of providing the best service to the customers. Besides, smart charging points can be linked to an app or online platform. This allows businesses to monitor and manage charging remotely and in real-time. If operators want to open up their charging points for public use, this data is critical to optimise pricing, availability and charging power to customers.

When a car is charged in a charge station operated by a smart charging system, the maximum energy limits is set by the operator. The operator automatically tests the connection between the vehicle and the device before they start charging. Since all charging events are monitored and can be controlled remotely, any unusual activity will be flagged by the charging operators' system. They can then resolve any issues without involving EV owners at all. Finally, smart charging could make powering EVs significantly cheaper receiving different energy rates in exchange for agreeing to charge at lower power at certain times to balance and settle the grid. For vehicle-to-grid operations, selling energy back to the grid could be a great source of extra income for EV owners.

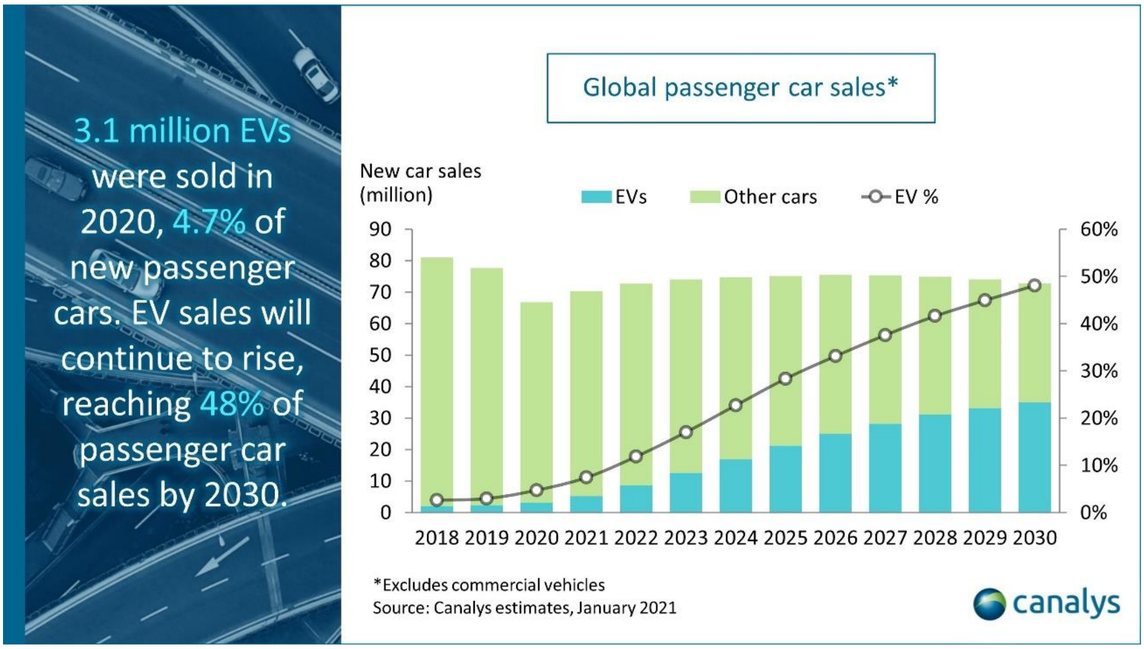


Figure 1: Global passenger cars sales 2019-2030. Source: Canalys estimates

According to the current forecasts (Figure 1), the number of EVs sold will rise to 30 million in 2028 and EVs will represent nearly half of all passenger cars sold globally by 2030. This means that EV charging infrastructure and, more specifically, smart charging management will play a vital role in the next decade. EVs have become the most significant addition to the electric load since the rise of air conditioning in the 1950s. Comparing the forecasted EV fleet with the current number of around 3 million electric vehicles on European roads, one can imagine the impact this will have on charging networks. All these additional electric vehicles will need charging facilities and energy networks able to handle this dynamically, optimising the costs for the operators, providing the best service to EV drivers and, at the same time, without overloading the grid.

The objective of SMAC product is to provide the benefits of smart charging to every CPOs and EV drivers in Europe. SMAC is conceived as a service involved in the interoperability platform INCAR (P5). That means that the information and charging operations related to EVs and CPOs will be managed by INCAR. The possibility to integrate SMAC service in the interoperability platform INCAR, allows the customer to have the same service independently of their EMSP, since the smart charging features of SMAC are available through the USER-CHI app linked directly to the CPO management system. This means that every time an EV driver joins in, INCAR performs a charging transaction at any charging point that supports smart charging and whose operator has joined the platform. SMAC will then be notified and it calculates the optimum charging profile for this recharge. The optimum charging profile represents the amount of power that should be delivered to a given charging session at a given moment. The optimum charging profile will be dynamically calculated by the SMAC algorithms based on several inputs, which are described in the following section.

3.2 Use cases

A use case is a technique for capturing the potential requirements of a new system. Each use case provides one or more scenarios that indicate how the system should interact with the user or with another system to achieve a specific goal. In other words, a use case is a sequence of interactions that will take place between a system and its actors, in response to an event that the main actor initiates on the system itself. The identification of use cases is the first step in SMAC implementation and defining what actually should be demonstrated during the project. Use cases define the scope of each SMAC functionality and describe how the platform will interact with users and other systems.

3.2.1 Background information for use case definition

SMAC use cases are focused on three main tasks:

1. To specify the inputs that the tool should take into account to calculate the optimal charging profiles.
2. To calculate the optimal charging profiles
3. To communicate the charging profile to the CPO management system.

Several inputs would be helpful for the calculation of the smart charging profiles. The information on vehicle features or the user desires related to the charging session could come from the EV driver. On the other hand, CPOs will be responsible for reporting charging stations relevant data. Smart charging inputs could also be classified into static or dynamic, depending on the frequency with which information will be sent to SMAC. An example of static input could be the maximum power a connector can deliver, as it is supposed it will not vary over time. On the other side, dynamic inputs are expected to be sent to SMAC often, for example, an EV driver could inform about the desired state of charge of the vehicle in each of the charging transactions performed.

The following table represents the whole set of inputs considered by a smart charging tool to calculate the optimal charging profiles, as well as the stakeholder who should report them and their type.

Table 1: Smart charging inputs

Input	Reported by	Type	Description
Demand forecast	CPO	Dynamic	Forecast of demand over the next 24 hours
Production forecast	CPO	Dynamic	Forecast of production/generation power over the next 24 hours
Supply point max. power	CPO	Static	Maximum power to be delivered simultaneously, considering non-controllable demand, production and EVSE-related demand
Supply point min. power	CPO	Static	Maximum power to be received simultaneously, for V2G operations
Energy price	CPO	Dynamic	The curve of energy price for cost optimisation
EV battery capacity	EV driver	Static	The capacity of the EV battery that is charging
EV SoC	CPO	Dynamic	Battery SoC of the EV that is charging
Nominal power of connectors	CPO	Static	Max. power the connector is able to deliver
Nominal discharge power of connectors	CPO	Static	Max. power the connector is able to receive, for V2G operations
Target slots	EV driver	Dynamic	The time when EV is required to be charged
Target SoCs	EV driver	Dynamic	Minimum SoC required by the EV at the target slot
Flex. Order	CPO	Dynamic	Support operations to the grid consisting of modifications on the supply point power flow limit (either upper, allowing greater demand, or lower, imposing demand limitations) provided by the grid operator
Opportunity cost	CPO	Static	Additional cost considered to disincentive long-lasting charging sessions

3.2.2 Use case definition methodology

Each use case is defined and documented in a dedicated use case table. The specification of each use case always follows the same format:

- Use Case Title: Identification code and descriptive name/title of the use case.
- Short description: Summary of the use case.

- Stakeholders: Anyone or anything that performs a behaviour (who is using the system). A use case defines the interactions between external stakeholders and the system under consideration to accomplish a goal. The stakeholders can be either natural persons or system stakeholders.
- Pre-conditions: Refer to the state of the system and its environment that is required before the use case starts. It can be helpful to use preconditions to clarify how the flow of events starts.
- Flow of events: The description of the normal, expected path through the use case. This is the path taken by most of the users most of the time.
- Expected results: This shows the expected outcomes after the use case execution.

3.2.3 Use cases list

In this section, the use cases that cover SMAC functionalities are presented following the structure described in section 3.2.2.

Table 2: UC - 001: CPO defines static inputs

Use case tittle	UC – 001: CPO defines static inputs
Short Description	A charge point operator specifies static information and restrictions to apply to a set of electric vehicle supply equipment.
Stakeholders	CPO who manages the charging stations
Preconditions	As SMAC will be integrated as a service of INCAR, the CPO has joined the platform and has shared their charging posts information by means of OCPI [3] protocol
Flow of events	• The CPO access to SMAC website for joined partners and navigate to the smart charging section • CPO choose the EVSE(s) that will share the same set of restrictions. This set of EVSEs will conform to what is called an optimisation context. • CPO introduces the static inputs for the selected set of EVSEs: Supply point maximum power, supply point

Use case tittle	UC – 001: CPO defines static inputs
	minimum power, connectors nominal discharge power of connectors and opportunity cost.
Expected results	SMAC is notified about the restrictions for the selected EVSEs and will take them into account when a charging transaction will be performed in any of them
Comments	• It is not mandatory to inform about all static inputs. If one of them is not reported, it will not be taken into account for the calculation of the charging profile. • The set of EVSEs specified with the restrictions is called optimisation context. • All inputs/restrictions specified will be shared for the set of EVSEs chosen (optimisation context), excepting nominal (discharge) power, which will be particular for each connector of the EVSE.

Table 3: UC - 002: CPO defines dynamic inputs

Use case tittle	UC – 002: CPO defines dynamic inputs
Short Description	A charge point operator specifies dynamic information and restrictions to apply to a set of electric vehicle supply equipment
Stakeholders	CPO who manages the charging stations
Preconditions	• As SMAC will be integrated as a service of INCAR, the CPO has joined the platform and has shared their charging posts information by means of OCPI protocol • The CPO has defined static restrictions for a set of EVSEs (optimisation context) • The CPO has implemented the proposed OCPI module
Flow of events	

Use case tittle	UC – 002: CPO defines dynamic inputs
	• CPO specify dynamic inputs for one of their optimisation context: demand and production forecasts, energy price and flexibility orders
Expected results	SMAC is notified about the restrictions for the selected EVSEs and will take them into account when a charging transaction will be performed in any of them
Comments	It is not mandatory to inform about all dynamic inputs. If one of them is not reported, it will not be taken into account for the calculation of the charging profile

Table 4: UC - 003: EV driver defines static inputs

Use case tittle	UC – 003: EV driver defines static inputs (i.e. battery capacity kWh)
Short Description	An EV driver specifies relevant information for the calculation of charging profiles
Stakeholders	EV driver
Preconditions	The EV driver has installed the USER-CHI mobile app on his/her device
Flow of events	• The EV driver navigates to the user profile section • The user specifies his/her EV battery capacity
Expected results	SMAC is notified about the battery capacity of the EV of the user and will take it into account when a charging transaction of the user will be performed
Comments	It is not mandatory to inform about the battery capacity. If it is not reported, it will not be taken into account for the calculation of the charging profile

Table 5: UC - 004: EV driver defines dynamic inputs

Use case tittle	UC – 004: EV driver defines dynamic inputs (i.e. desired SoC)
Short Description	An EV driver specifies information for the calculation of charging profile when he/she wants to start a charging transaction
Stakeholders	EV driver
Preconditions	The EV driver has installed the USER-CHI mobile app in his/her device
Flow of events	• Before starting the charging transaction, the USER-CHI mobile app displays a form which contains the dynamic inputs from the user: the desired SoC at the end of the transaction and the expected departure time • The user introduces the required information
Expected results	SMAC is notified about the data introduced by the user and will take them into account for the calculation of the charging profiles of the ongoing transaction
Comments	It is not mandatory to inform about all dynamic inputs. If one of them is not reported, it will not be taken into account for the calculation of the charging profile

Table 6: UC - 005: Charging profile calculation

Use case tittle	UC – 005: Charging profile calculation
Short Description	SMAC calculate charging profiles for charging transactions
Stakeholders	• SMAC • CPO • INCAR
Preconditions	• The CPO has previously introduced the smart charging inputs for the charging station where the transaction is performed • The user has introduced the dynamic and static inputs that EV drivers can specify
Flow of events	• The CPO has notified the beginning of a charging transaction by means of OCPI protocol • The charging session information is sent to SMAC by INCAR platform

Use case tittle	UC – 005: Charging profile calculation
	• From the data available in the charging session, SMAC identifies the smart charging input related to the EV driver who performs the charging, and the inputs associated with the charging point that is operating the transaction
Expected results	SMAC algorithms calculate the optimum charging profile based on the inputs for the ongoing session

Table 7: UC - 006: Reporting charging profile

Use case tittle	UC – 006: Reporting charging profile
Short Description	SMAC reports the calculated charging profile to the charging point
Stakeholders	• SMAC • CPO • INCAR
Preconditions	The steps described in UC-005 have been performed
Flow of events	• SMAC reports the charging profile to INCAR platform by means of the OCPI protocol • INCAR reports the charging profile to the backend of the CPO who operates the charging point by means of OCPI protocol • The CPO send the order to the charging point to apply the received charging profile
Expected results	The charging station delivers the energy specified in the charging profile

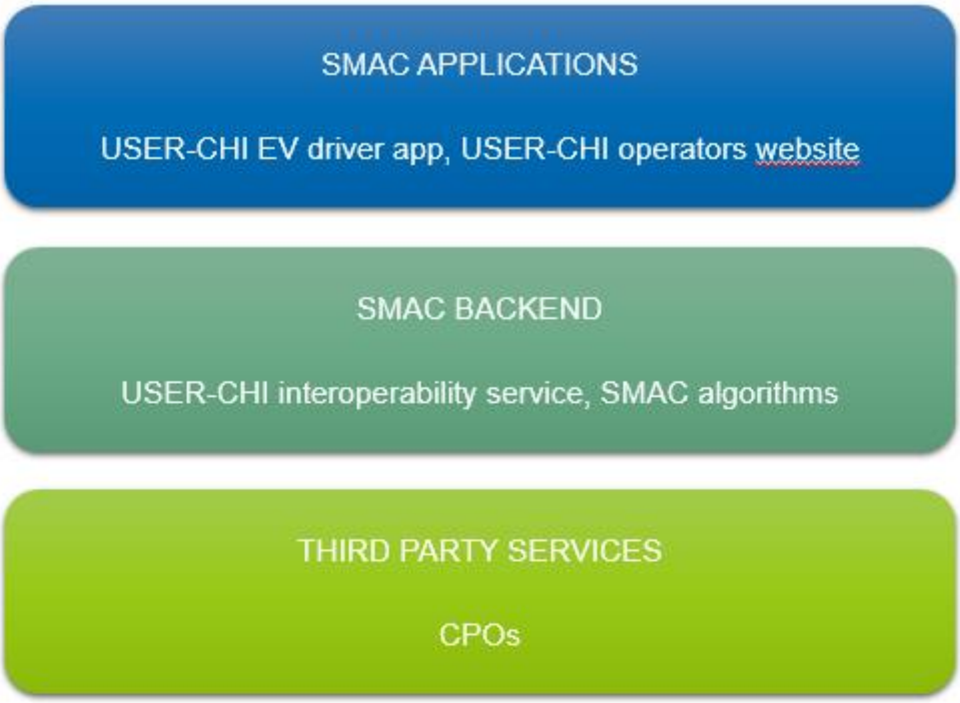
3.3 Functional blocks

This section includes the different functional components and blocks in which the system has been classified.

SMAC is conceived as a service of the INCAR platform. With this approach, whenever an EV driver or a CPO joins INCAR, the services offered by SMAC will be automatically available for them. Taking this into account, preliminary design works led to the conclusion that SMAC graphic user interfaces for end-users would be included in INCAR webpage and mobile app. EV drivers make use of INCAR app to perform any operation related to a charging transaction such as search available charging points, make reservations, start transactions, etc. The only situation in which the user should interact with SMAC in a direct manner is when introducing the EV smart charging inputs, a task that could be included perfectly in the INCAR app. On the other hand, CPOs will be allowed to introduce their smart charging inputs, in this case by means of a web instead of a mobile app. As INCAR will offer a website to all platforms (EMSPs and CPOs) joined, it has more sense to include a section for the configuration of smart charging inputs for CPOs, rather than develop a different web application just related to SMAC.

With this clarification and after the analysis of uses cases presented in section 3.2.3, it is possible to establish and categorise the SMAC components in three layers, as it is shown in Figure1:

Figure 2: SMAC layers



- Applications: the actual pieces of software serving as a human-machine interface of SMAC, each one specialised in a particular set of use cases. Applications can be apps for mobile devices or web applications.
- Backend: each of the services included in SMAC, designed and developed to offer a specialised interface to the applications and to the rest of the services of the backend. Services shall run continuously in the hosting platform and be ready to receive requests from the client for their functionality.
- Third-party services: continuous iteration with external CPOs platforms shall be necessary in order to perform any functionality to be offered to final users by means of SMAC services.

3.3.1 EV driver app

USER-CHI mobile app is the tool offered to the EV drivers to use all functionalities and services provided by INCAR and SMAC. Apart from all INCAR services related to interoperability, accounting and routing issues described in the deliverable D3.1, the EV driver app will also take a relevant part in the SMAC ecosystem. As it was previously explained, there will be a set of relevant smart charging inputs that will be defined by the EV driver by means of the mobile app. It is important to remark that SMAC will be able to calculate charging profiles for any transaction even if the user does not introduce the EV battery capacity, the current SoC, the expected departure time or the expected SoC, but, as expected, the performance of the charging profile defined by SMAC will be better if more inputs are notified. With the aim of informing SMAC with as many inputs as possible, the EV driver app will display different sections where the user can introduce them. As it was explained in the use case section, the inputs from the driver could be categorised as static or dynamic:

- Static inputs. We are considering just one static input from the driver: the EV battery capacity. It is considered static because it is supposed that this information will not change over time in the different charging transactions of the user. This data will be displayed in the configuration of the user profile of the app, where he/she will be able to specify a value for it, as well as other information related to the profile such as email, password, etc. Although this information is considered static, if there is the case, for example, if the driver buys a new vehicle, it is possible to modify it also in this app section.
- Dynamic inputs. The smart charging dynamic inputs that EV drivers are allowed to report are the expected departure time and the expected SoC at the end of the recharge. They are considered dynamic because they vary for each charging transaction depending on the situation of the driver. As they are dynamic, they are required to the final user in a form before starting the recharge.

Once the end-user introduces any of the smart charging inputs, these will be communicated to INCAR interoperability and roaming services, and this one will redirect the information to SMAC.

3.3.2 USER-CHI operators website

Once a platform conformed by EMSPs and/or CPOs joins INCAR, they will be provided with credentials in order to access USER-CHI operators website. This web will have a section dedicated to the dynamic load management of charging stations, where the operators could specify different smart charging inputs. In the same way as EV driver smart charging inputs, SMAC will be able to calculate charging profiles for any transaction even if the operator of the stations does not define any kind of inputs for their rechargers, although in this case the effectiveness of SMAC could be limited. The CPO smart charging inputs can be also classified into static or dynamic:

- Static inputs. The set of static inputs which can come from the CPO are supply point minimum and maximum power, the nominal charge and discharge power of connectors, and the opportunity cost. For the specification of this data, in the first moment, the website will display the whole set of the EVSEs that the CPO manages, and the operator will have to choose the subset to which the smart charging inputs will be applied. Once the CPO has selected this subset, the operator could specify the mentioned inputs. This combination of the selected EVSEs and the given static inputs is called optimisation context. As in the previous case, although this information is considered static, if there is a case it is possible to modify it in the website section.
- Dynamic inputs. The smart charging dynamic inputs that CPOs are allowed to report are demand and production forecasts, energy price and flexibility orders. Before defining dynamic inputs, the CPO shall have established an optimisation context. If it were the case, the operator would have to choose one of his/her associated optimisation contexts and finally introduce the dynamic inputs for the selected set of EVSEs. Additionally, the CPO can provide the state of charge of the EVs which are charging in their stations. These inputs are considered dynamic because it is assumed they will vary over time frequently.

In the same way as the EV driver case, once the operator introduces any of the smart charging inputs, these will be communicated to INCAR interoperability and roaming services, and this one will redirect the information to SMAC.

3.3.3 INCAR backend services

As smart charging services will be part of the INCAR platform, the INCAR backend will centralise the communication of the smart charging inputs between the final users (EV drivers and CPOs) and SMAC. Additionally, every time SMAC calculate a smart charging profile for an ongoing session, this charging profile will be sent to INCAR interoperability and roaming services. Finally, the platform interoperability service will inform the CPO who manages the charging station of the ongoing transaction about the optimal charging profile calculated by SMAC.

3.3.4 SMAC backend

Whenever a transaction starts in a charging point, which supports smart charging, the SMAC backend will start the calculation of the optimal charging profile. Intending to perform this calculation with the maximum accuracy, SMAC checks if the CPO has specified an optimisation context for the location where the recharging is occurring. If so, SMAC obtains the smart charging inputs which the CPO introduced in the INCAR web. Additionally, the static and dynamic inputs that the EV driver has specified will be included in the session information provided by the INCAR interoperability service. With the available data from CPO and EV driver, the SMAC backend calculates the optimal charging profile for the ongoing session and reports it to the INCAR roaming service, which is in charge of sending the profile to the operator of the charging point.

3.3.5 CPOs platforms

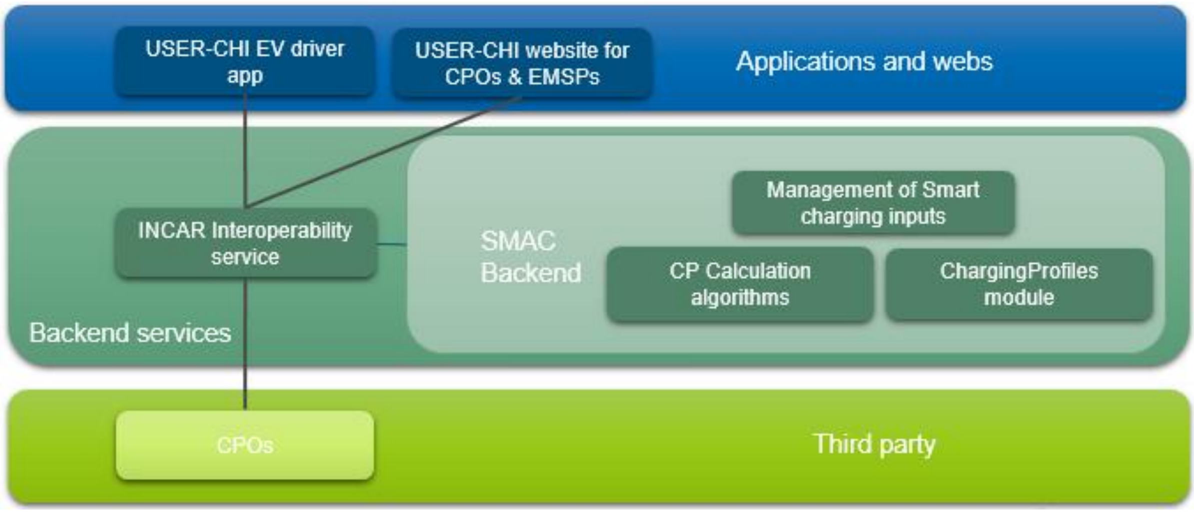
Charging point operators have the possibility of sending orders to charging stations and perform any kind of operation related to chargers. This means neither SMAC nor INCAR are allowed to communicate directly with the posts. Firstly, they shall interact with the CPO to inform it about the charging profile and afterwards the CPO would have to send the corresponding command to the charging station to apply the received charging profile. The communication between the CPO control systems and their charging stations is out of the scope of SMAC and INCAR products.

4. Smart grid services technical design

The purpose of this section is to start to show the services, their workflow and how they communicate internally, with end-user devices or with third party services.

The design of SMAC components such as applications, webs and services, under the technical perspective, follows the schema defined in section 3.3. The set of services, apps and relationship between them can be appreciated in Figure 3:

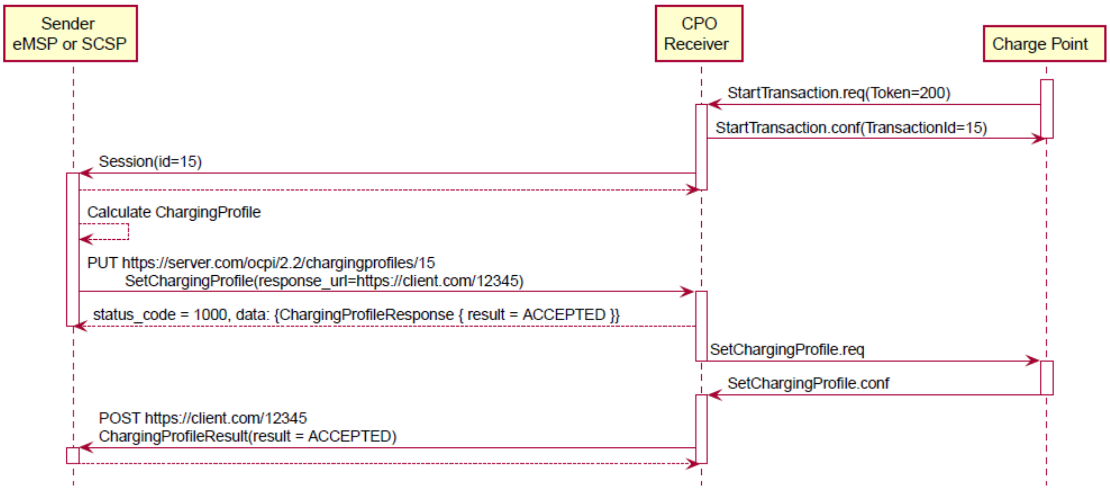
Figure 3: SMAC components



As it has been explained previously, SMAC is conceived as a service of the INCAR platform. Besides providing smart charging services, one of the main aims of INCAR is to enable EVs to be charged at an EVSE regardless of whether the owner/user of the vehicle has a contract with the provider that operates the charging point or not, and in a transparent manner. This is possible thanks to the standard protocol OCPI. This protocol set the basis of INCAR interoperability service, which has a relevant part in the SMAC tool. The platform interoperability services are designed and developed following the specifications of the OCPI market role called Hub. In the OCPI EV Charging market roles classification (see OCPI 2.3) we can identify another market role present in the above Figure 2: the CPO. Finally, in this section we can find a market role description, which fits perfectly with the purpose of the USER-CHI smart charging tool, the SCSP: "*Smart Charging Service Provider, provided smart charging service to other parties might use a lot of different inputs to calculate Smart Charging Profiles*". As OCPI protocol defines the way the

CPOs, Hubs and SCSPs shall communicate, the iteration between the third-party services (CPOs), and the backend services (interoperability services or Hub and SMAC backend or SCSP) will be performed by means of the implementation of this protocol. The following Figure 4 extracted from OCPI documentation represents the basic workflow related to smart charging operations:

Figure 4: OCPI smart charging workflow



The approach proposed for USER-CHI smart charging services is similar to the one shown in Figure 4, but in this case, the communication between CPOs and the smart charging service provider (SMAC) will be centralised by the INCAR backend.

4.1 Reporting smart charging inputs

Although OCPI protocol states that the smart charging profiles will be calculated from different inputs, it does not clarify which information should be taken into account for the calculation nor the way they shall be reported. In previous chapters, it has been stated the different inputs SMAC shall consider. Some of these data are included in the OCPI specification but other ones are not covered by the protocol. Consequently, it will be necessary to design and develop a mechanism to transmit the data not presented in OCPI. . In the following section, it will be clarified how the whole set of smart charging inputs should be communicated.

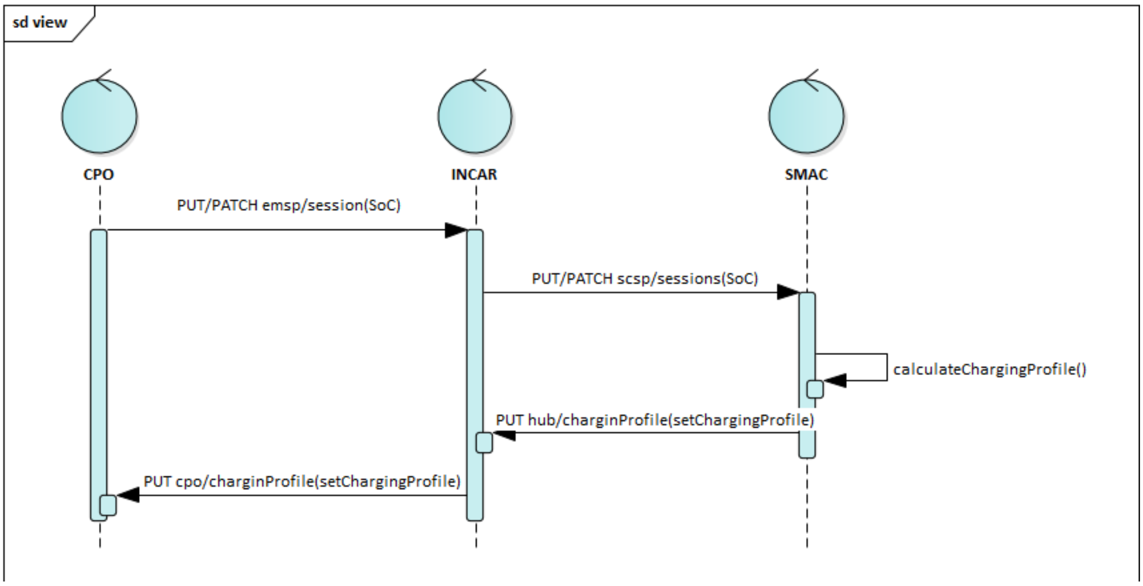
4.1.1 Data covered by OCPI

Among the smart charging inputs explained in section 3.2, the ones which are present in OCPI specification are the nominal power of connectors, the user expected departure time and the user expected SoC:

- **Nominal power of connector.** The maximum power that a connector can deliver is considered a part of the static information that should be given by the CPO. Following the OCPI locations module specification, whenever a CPO notifies to INCAR platform about the charging stations they manage, they can include in the charger information the maximum electric power that can be supplied by their connectors. In case this data is not reported, it can be calculated easily from the maximum amperage and maximum voltage, data that must be given.

- **State of charge of the EV:** OCPI makes it possible to provide SoC during the charging session. When the CPO sends the session information of an ongoing smart charging transaction, this data will be received by SMAC and taken into account for the recalculation of the charging profile associated with the reported session.

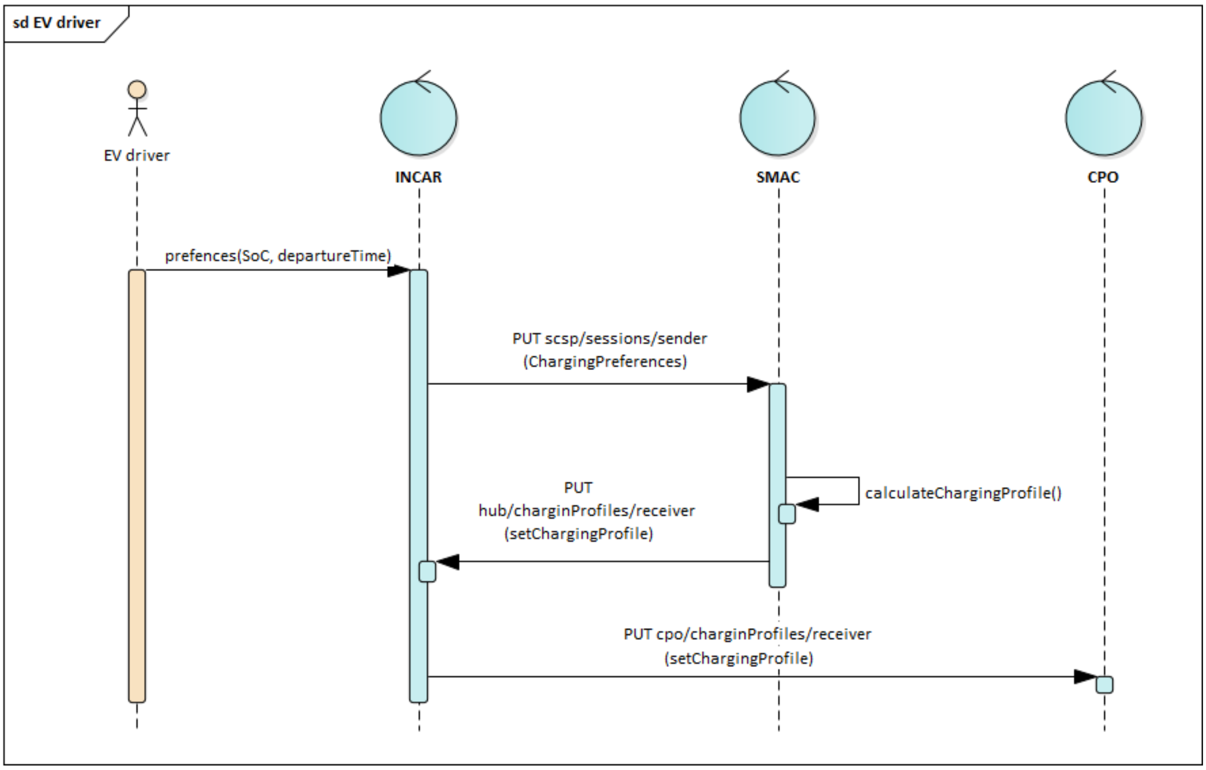
Figure 5: SoC workflow



- **Expected departure time:** The time when EV is required to be charged is a piece of information that the final users can specify for each one of their recharges. Under the OCPI specification, the driver optionally introduces this data for an ongoing session. In that case, this input is notified to INCAR through a PUT request on the sender interface of the OCPI sessions module. The following step consists of redirecting this information from the platform to SMAC. Therefore, it is proposed the implementation of the sender interface of the OCPI sessions module in the market role SCSP, an implementation that is not considered typical in the current protocol version.
- **Expected state of charge:** The workflow for the minimum expected SoC by the driver at the end of the charging transaction is similar to the expected departure time. The OCPI session module defines how the expected SoC can be reported for an ongoing

session. SMAC would be notified about the SoC for the smart charging profile calculation.

Figure 6: EV driver preferences workflow



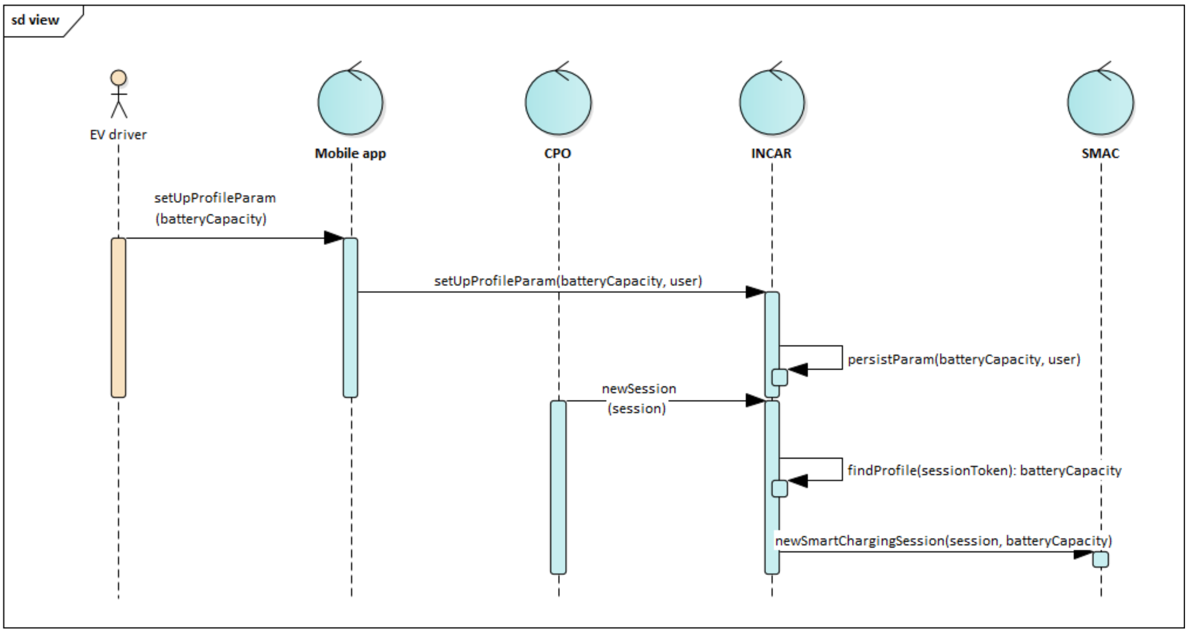
4.1.2 Data not covered by OCPI

Apart from the smart charging data presented in the above section, there is more relevant input for the optimal performance of SMAC services that could be notified by EV drivers or CPOs, such as EV battery capacity and the maximum power to be delivered simultaneously in a single supply point.

4.1.2.1 Data from EV drivers

The EV battery capacity is not defined under the scope of the OCPI protocol. As explained in section 3.3.1, this information can be provided by the mobile app. The users' profile information, which includes EV battery capacity, is managed by the INCAR backend. In this profile, information will be also present on the OCPI token object (see OCPI 12 section) which identify each one of the EV drivers involved in the platform. OCPI specifies that charging session data must include the EV driver token. In this way, every time a CPO reports a session, the platform backend will be able to identify the user profile and the configured battery capacity from the token present in the session object. Once the backend knows the value of the battery capacity for the driver who is present in the session object, it is included in the object and redirected to SMAC.

Figure 7: battery capacity workflow



With this approach, the session object exchanged between INCAR and SMAC is modified with the inclusion of the battery capacity. As these data are redirected to neither CPOs nor EMSPs, it is not required any kind of modification in their systems that manage OCPI communications.

4.1.2.2 Data from CPOs

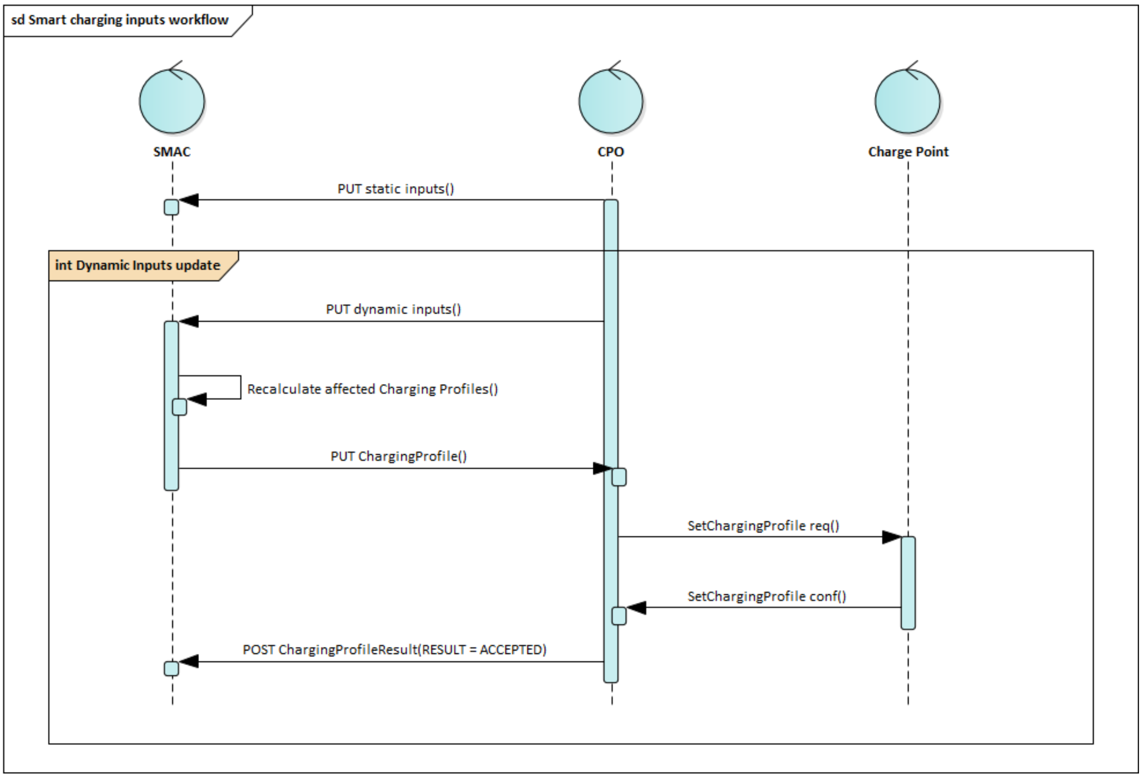
As explained previously, one of the USER-CHI website sections is intended to allow CPOs to set up restrictions related to the charging stations they manage.

The graphic user interface elements of the website and the possible inputs have been explained in section 3.3.2, but still, it is not defined how the operator web will be able to inform SMAC about this data. Figure 3 represents the workflow related to smart charging profiles in OCPI although the protocol does not have any section dedicated to smart charging inputs in which is specified the considered relevant information for the calculation of charging profiles or the way they shall be reported. With the aim of providing this lack of information, and considering that OCPI could not just be limited to define the workflow of smart charging profiles, a new OCPI module is proposed in the following chapter.

5. SmartChargingOptimisation module specification

The smart charging optimisation module gives SCSPs knowledge of the smart charging inputs of charging stations owned by a CPO. This module implements two main functions, which are represented in the following figure:

Figure 8: Smart charging optimisation module workflow



- Firstly, the CPO configures the required set of static smart charging optimisation inputs. Basically, these optimisation inputs define how a list of one or several EVSEs need to be considered together in the calculation of the optimum smart charging profiles (e.g. because they are connected to a common supply point with specific constraints), as well as other relevant static data to be considered by SMAC optimisation algorithms

- Regularly, CPO updates dynamic information that needs to be considered by the algorithms that compute the optimum charging profiles

5.1.1 Flow and lifecycle

5.1.1.1 Push model

When the CPO creates a new smart charging optimisation object for a set of rechargers, the CPO sends them to the SCSPs by calling the PUT method on the SCSP smart charging optimisation endpoint with the newly created object.

Any changes to the smart charging optimisation object in the CPO´s system can be sent to the SCSP system by calling the PUT or the PATCH method on the SCSP smart charging optimisation endpoint with the updated object.

When the CPO deletes a smart charging optimisation, CPO will update the SCSP system by calling DELETE on the SCSP smart charging optimisation endpoint with the ID of the deleted object.

When the CPO is not sure about the state or existence of a smart charging optimisation object in the system of a SCSP, the CPO can use a GET request to validate the smart charging optimisation object in the SCSP's system.

5.1.1.2 Pull model

SCSPs who do not support the Push model need to call GET on the CPO´s smart charging optimisation endpoint to receive all smart charging optimisation data.

5.1.2 Interfaces and endpoints

There is both a Sender and a Receiver interface for smart charging optimisation. Advised is to use the push direction from Sender to Receiver during normal operation.

5.1.2.1 Sender interface

Typically implemented by market roles like CPOs.

The Sender's smart charging optimisation interface gives the Receiver the ability to request smart charging optimisation information.

Table 8: Smart charging optimisation module sender interface

Method	Description
GET	Returns smart charging optimisation objects, last updated between the {date_from} and {date_to} (paginated)
POST	n/a
PUT	n/a
PATCH	n/a
DELETE	n/a

5.1.2.1.1 GET method

Fetch information about all smart charging optimisations.

Endpoint structure definition:

```
{smartChargingOptimisation_endpoint_url}?[date_from={date_from}]&[date_to={date_to}]&[offset={offset}]&[limit={limit}]
```

Examples:

```
https://www.server.com/ocpi/cpo/2.2/smartChargingOptimisation/?date_from=2019-01-8T12:00:00&date_to=2019-01-29T12:00:00
```

```
https://ocpi.server.com/2.2/smartChargingOptimisation/?offset=50
```

```
https://www.server.com/ocpi/2.2/smartChargingOptimisation/?date_from=2019-01-29T12:00:00&limit=100
```

```
https://www.server.com/ocpi/cpo/2.2/smartChargingOptimisation/?offset=50&limit=100
```

Request Parameters

If additional parameters: {date_from} and/or {date_to} are provided, only smart charging optimisations with last_updated between the given {date_from} (including) and {date_to} (excluding) will be returned.

This request is paginated, it supports the pagination related URL parameters.

Table 9: Smart charging optimisation – Sender GET request parameters

Parameter	Datatype	Required	Description
date_from	DateTime	no	Only return smart charging optimisations that have last_updated after or equal to this Date/Time (inclusive).
date_to	DateTime	no	Only return smart charging optimisations that have last_updated up to this Date/Time, but not including (exclusive).

Parameter	Datatype	Required	Description
offset	int	no	The offset of the first object returned. Default is 0.
limit	int	no	Maximum number of objects to GET.

Response Data

The endpoint returns an object with a list of valid smart charging optimisations, the header will contain the pagination related headers.

Any older information that is not specified in the response is considered no longer valid. Each object must contain all required fields. Fields that are not specified may be considered as null values.

Table 10: Smart charging optimisation – Sender GET response data

Type	Card.	Description
SCOptimisation	*	List of all smart charging optimisations

5.1.2.2 Receiver interface

Typically implemented by market roles like: SCSP.

Smart charging optimisations are Client Owned Objects, so the endpoints need to contain the required extra fields: {party_id} and {country_code}.

Endpoint structure definition:

{smartChargingOptimisation_endpoint_url}/{country_code}/{party_id}/{optimisation_id}

Example:

```
https://www.server.com/ocpi/scsp/2.2/smartChargingOptimisation/BE/BEC/12
```

Table 11: Smart charging optimisation module receiver interface

Method	Description
GET	Retrieve a smart charging optimisation as it is stored in the SCSP's system
POST	n/a
PUT	Push new/updated smart charging optimisation object to the SCSP
PATCH	Update existing smart charging optimisation object
DELETE	Remove a smart charging optimisation object which is no longer in use and will not be used in future either

5.1.2.2.1 GET method

If the CPO wants to check the status of a smart charging optimisation in the SCSP's system, it might GET the object from the SCSP's system for SCSP's purposes. After all, the CPO is the owner of the object, so it would be illogical if the SCSP's system had a different status or was missing the object entirely.

Request parameters

The following parameters can be provided as URL segments

Table 12: Smart charging optimisation – Receiver GET request parameters

Parameter	Datatype	Required	Description
country_code	CiString(2)	yes	Country code of the CPO performing the GET request on the SCSP's system.
party_id	CiString(3)	yes	Party ID (Provider ID) of the CPO performing the GET request on the SCSP's system.
id	CiString(36)	yes	Optimisation.id of the smart charging optimisation object to retrieve.

Response data

The response contains the requested object.

Table 13: Smart charging optimisation – Receiver GET response data

Type	Card.	Description
SCOptimisation	1	The requested smart charging optimisation object

5.1.2.2.1.1 PUT method

New or updated smart charging optimisation objects are pushed from the CPO to the SCSP.

Request Body

In the PUT request, the new or updated smart charging optimisation object is sent in the body.

Table 14: Smart charging optimisation – Receiver PUT body

Type	Card.	Description
SCOptimisation	1	The requested smart charging optimisation object

Request parameters

The following parameters can be provided as URL segments.

Table 15: Smart charging optimisation – Receiver PUT URL segments

Parameter	Datatype	Required	Description
country_code	CiString(2)	yes	Country code of the CPO performing the PUT request on the SCSP's system.
party_id	CiString(3)	yes	Party ID (Provider ID) of the CPO performing the PUT request on the SCSP's system.
id	CiString(36)	yes	Optimisation.id of the smart charging optimisation object to create or replace.

Example: add a smart charging optimisation object

```
PUT To URL: https://www.server.com/ocpi/scsp/2.2/optimisation/BE/BEC/1
```

```
{
	"country_code": "BE",
	"party_id": "BEC",
	"id": "1",
	"evses": [{
		"location_id": "1",
		"evse_uid": "1",
		"connectors": [{
			"connector_id": "1",
			"power": 5000,
			"discharge_power": 0,
		},
		{
			"connector_id": "2",
			"power": 5000,
			"discharge_power": 100,
	}],

	"max_power": 10000,
	"min_power": 0,
	"opportunity_cost": 10,
	"last_updated": "2015-06-29T22:39:09Z"
}
```

5.1.2.2.1.2 PATCH method

Same as the PUT method, but only the fields/objects that need to be updated have to be present. Fields/objects which are not specified are considered unchanged.

Any request to the PATCH method SHALL contain the last_updated field.

Example: update optimisation inputs

```
PATCH https://www.server.com/ocpi/scsp/2.2/optimisation/NL/TNM/1
```

```
{
"demand":[{
       "value": 4000,
       "time_slot": "2015-06-29T22:49:09Z"
},{
       "value": 5000,
       "time_slot": "2015-06-29T23:49:09Z"
}],
"generation":[{
       "value": 3000,
       "time_slot": "2015-06-29T22:49:09Z"
},{
       "value": 3500,
       "time_slot": "2015-06-29T23:49:09Z"
}],
"price":[{
       "value": 10,
       "time_slot": "2015-06-29T22:49:09Z"
},{
       "value": 5,
       "time_slot": "2015-06-29T23:49:09Z"
}],
"flex_orders":[{
       "value": 5,
       "time_slot": "2015-06-29T22:49:09Z"
},{
       "value": 5,
       "time_slot": "2015-06-29T23:49:09Z"
}],
}
```


5.1.2.2.1.3 DELETE method

Delete a smart charging optimisation object which is not used any more and will not be used in future either.

Request parameters

The following parameters can be provided as URL segments.

Table 16: Smart charging optimisation – Receiver DELETE request parameters

Parameter	Datatype	Required	Description
country_code	CiString(2)	yes	Country code of the CPO performing the DELETE request on the SCSP's system.
party_id	CiString(3)	yes	Party ID (Provider ID) of the CPO performing the DELETE request on the SCSP's system.

Parameter	Datatype	Required	Description
id	CiString(36)	yes	Optimisation.id of the smart charging optimisation object to delete.

5.1.3 Object description

5.1.3.1 SCOptimisation object

Table 17: Smart charging optimisation object

Property	Type	Card.	Description
country_code	CiString(2)	1	ISO-3166 alpha-2 country code of the CPO that 'owns' this optimisation context.
party_id	CiString(3)	1	CPO ID of the CPO that 'owns' this optimisation context (following the ISO-15118 standard).
id	CiString(36)	1	The unique id that identifies the optimisation context in the CPO platform.
max_power	number	?	Maximum power to be delivered simultaneously, considering, non-controllable demand, production and EVSE-related demand (W)
min_power	number	?	Minimum power at the supply point, particularly relevant on scenarios V2G (W)
evses	Evse	+	EVSEs to apply the smart charging optimisation
opportunity_cost	number	?	Linearly-increasing additional cost considered to disincentive long-lasting charging sessions [€/slot]
demand	Demand	*	Local demand forecasts (one element per optimisation time slot)
generation	Generation	*	Local generation forecasts (one element per optimisation time slot)
price	Price	*	Energy price (one element per optimisation time slot)
flex_orders	FlexOrders	*	Grid operator flexibility orders to be fulfilled
last_updated	DateTime	1	Timestamp when this object was last updated (or created)

5.1.3.1.1 Examples

SCOptimisation example


```
{
	"country_code": "BE",
	"party_id": "BEC",
	"id": "1",
	"evses": [{
		"location_id": "1",
		"evse_uid": "1",
		"connectors": [{
			"connector_id": "1",
			"power": 5000,
			"discharge_power": 0,
		},
		{
			"connector_id": "2",
			"power": 5000,
			"discharge_power": 100,
	}],
	"demand":[{
		"value": 4000,
		"time_slot": "2015-06-29T22:49:09Z"
	},{
		"value": 5000,
		"time_slot": "2015-06-29T23:49:09Z"
	}],
	"generation":[{
		"value": 3000,
		"time_slot": "2015-06-29T22:49:09Z"
	},{
		"value": 3500,
		"time_slot": "2015-06-29T23:49:09Z"
	}],
	"price":[{
		"value": 10,
		"time_slot": "2015-06-29T22:49:09Z"
	},
	{
		"value": 5,
		"time_slot": "2015-06-29T23:49:09Z"
	}],
	"flex_orders":[{
		"value": 5,
		"time_slot": "2015-06-29T22:49:09Z"
	},
	{
		"value": 5,
		"time_slot": "2015-06-29T23:49:09Z"
	}],
	"max_power": 10000,
```

```
        "min_power": 0,
        "opportunity_cost": 10,
        "last_updated": "2015-06-29T22:39:09Z"
}
```

5.1.4 Data types

5.1.4.1 EVSE

Table 18: EVSE object

Property	Type	Card.	Description
location_id	CiString(36)	1	Location.id of the Location (belonging to the CPO) on which the optimisation context should be applied.
evse_uid	CiString(36)	1	EVSE.uid of the Location.EVSE (belonging to the CPO) on which the optimisation context should be applied.
connectors	Connector	+	Set of connectors of the evse, including nominal charge and discharge power

5.1.4.2 Connector

Table 19: Connector object

Property	Type	Card.	Description
connector_id	number	1	Id of the Location.EVSE.connector (belonging to the CPO) on which the optimisation context should be applied.
power	number	1	Nominal power [kW]
discharge_power	number	?	Nominal discharge power [kW]

5.1.4.3 Demand

Table 20: Demand object

Property	Type	Card.	Description
time_slot	DateTime	1	Time slot where demand value applies
value	number	1	Forecasted demand [kWh]

5.1.4.4 Generation

Table 21: Generation object

Property	Type	Card.	Description
time_slot	DateTime	1	Time slot where demand value applies
value	number	1	Forecasted generation [kWh]

5.1.4.5 Price

Table 22: Price object

Property	Type	Card.	Description
time_slot	DateTime	1	Time slot where demand value applies
value	number	1	Energy price [€/kWh]

5.1.4.6 FlexOrders

Table 23: Flexibility orders object

Property	Type	Card.	Description
time_slot	DateTime	1	Time slot where demand value applies
value	number	1	Required offsets over the maximum power at supply point (usually the contracted power) [kW]

5.2 Proposed data to be included in OCPI

The SmartChargingOptimisation module is intended to define the relevant information that a smart charging service provider should take into account for the optimisation of the charging profiles as well as the workflow to report them. It has been considered appropriate to group this functionality in a new OCPI module due to the high number of communications affecting INCAR and SMAC products covered by this protocol.

The following table represents the proposed implementation of smartChargingOptimisation by the different OCPI roles as well as the modifications regarding Sessions module in order to report SMAC the EV driver inputs covered by OCPI: expected departure time and expected state of charge. The table shows the typical communication role: Receiver, Sender or Both.

Table 24: Proposed OCPI modules and roles

Module	CPO	HUB	SCSP
SmartChargingOptimisation	Sender	Both	Receiver
Sessions	Sender (no change)	Both (no change)	Both

As shown in the table, the CPO is the sender of the data covered by the new module. Consequently, the CPO shall implement the sender interface of the module and their systems must be able to communicate the smart inputs information for the calculation of the charging profiles. In order to facilitate the development efforts of the CPOs involved in the project, they could set up the set of static smart charging inputs, called optimisation context, in a dedicated website. Dynamic inputs are not considered in this website, since they will vary frequently over the time. Rather than introduce them in a web form, which could be a tedious task for the operator, the dynamic inputs are communicated by web services in the same way as the rest of OCPI modules.

The Smart Charging Optimisation module presented in this section is intended to be included in the standard protocol OCPI. OCPI specifies the relevant operations and exchange of information that should be performed between the different parties involved in the electromobility scenario in order to solve interoperability issues. A module dedicated to smart charging operations has been included in the last protocol version, but there is not any session dedicated to the data to be considered in the calculation of the smart charging profiles, nor the way this information shall be reported. As we consider this is a crucial previous step to be performed prior to calculating the charging profiles, our intention is to send the module designed and described in this deliverable to The EVRoaming Foundation[1] in order to be included in the standard. This step will be performed in the scope of the WP8 tasks, which are related with replication plans, scale-up and business model analysis

5.3 SMAC calculation algorithms

In previous sections, it has been explained the different smart charging inputs SMAC can use for the calculation of the charging profiles, as well as the way they need to be send. SMAC database will hold these data, which will be queried for the charging profile calculation every time a charging session starts in a station which supports smart charging operations.

---

[1] https://evroaming.org/about-us/

Finally, the algorithms which calculate the optimal charging profile for an ongoing session will be designed based on a linear optimisation model. The following sections describe all required inputs, constraints, variables and objective function of the proposed models. All models considered temporal scope as a number of time slots, of a particular duration (e.g. 15 minutes). The total amount of slots gives the time horizon of the optimisation (e.g. 96 slots of 15 minutes). The properties of any linear optimisation model include:

- Inputs: invariable data that describes the optimisation context
- Variables: data that the algorithm is allowed to change when calculating the optimum (usually the expected results of the optimisation)
- Constraints: constraints to the values the (combination of) variables need to fulfil
- Objective function: function (dependent on the variables) the algorithm seeks to minimise/maximise

The following definitions apply to all described models:

- Ts: timespan of each slot (in minutes)
- T: number of slots. Time horizon of the optimisation is therefore Ts * T
- N: number of EVSEs with active charging sessions

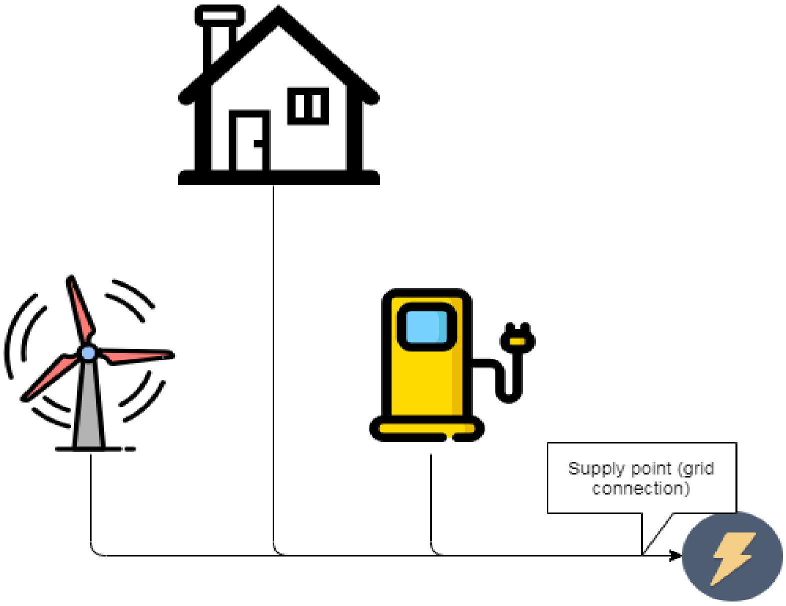
5.3.1 Optimum charging profiles considering CPO and driver requirements

This version of the model has the following context:

- On-site non-controllable demand
- On-site generation
- Limitation of total (imported) power at the on-site supply point
- No V2G schemes are considered

CPO objective is to minimise the cost of the energy imported from the grid. This objective is (implicitly) similar to the maximisation of self-consumption (since on-site generation costs are assumed 0).

Figure 9: Optimum charging profile based on smart charging inputs



Formal model description

Inputs

- I1.1 Non-controllable on-site demand power forecast (kW)

$$Demand_t \; t \in [0, T-1]$$

- I1.2 On-site production (generation) power forecast (kW)

$$Production_t \; t \in [0, T-1]$$

- I1.3 Limitation of total (imported) power at on-site supply point (kW)

$$SupplyPointPMax$$

- I1.4 Imported energy price (€/kWh)

$$Price_t \; t \in [0, T-1]$$

- I1.5 Total battery capacity (kWh) per EV (to facilitate readout, identified by the EVSE it is connected to)

$$EVSECapacity_n \; n \in [0, N-1]$$

- I1.6 Battery initial SoC (kWh) per EV (to facilitate readout, identified by the EVSE it is connected to)

$$EVSESoC_n \; n \in [0, N-1]$$

- I1.7 EVSE nominal power (kW)

$$EVSEPower_n \; n \in [0, N-1]$$

- I1.8 Target slot per EV (time when EV is required to be charged)

$$TargetSlot_n \; n \in [0, N-1]$$

- I1.9 Target SoC (ratio of total battery capacity) required at target slot per EV

$$TargetSoC_n \; n \in [0, N-1]$$

Variables

- V1.1 Energy to be delivered per EVSE and slot (kWh). These (reinterpreted in terms of power) will compose the charging profiles per EVSE

$$EVSEEnergy_{n,t} \; n \in [0, N-1] \; t \in [0, T-1]$$

- V1.2 Energy flows at supply point (kWh)

$$SupplyPointEnergy_t = \sum_{n=1}^{N} EVSEEnergy_{n,t} + (Demand_t + Production_t) \cdot \frac{Ts}{60}$$

$$t \in [0, T-1]$$

- V1.3 EV battery SoC (kWh) at the end of each slot

$$EVSESoC_{n,t} = EVSESoC_{n,t-1} + EVSEEnergy_{n,t} \;\; n \in [0, N-1], t \in [0, T-1]$$

Constraints

- C1.1 EV battery SoC cannot be lower than 0

$$EVSESoC_{n,t} \geq 0 \;\; n \in [0, N-1], t \in [0, T-1]$$

- C1.2 EV battery SoC cannot exceed battery capacity

$$EVSESoC_{n,t} \leq EVSECapacity_n \;\; n \in [0, N-1], t \in [0, T-1]$$

- C1.3 EV battery SoC at disconnection slot must fulfil target SoC requirement

$$EVSESoC_{n,\mathrm{TargetSlot}_n} \geq EVSECapacity_n \cdot TargetSoC_n \;\; n \in [0, N-1]$$

- C1.4 Power flow at supply point must not exceed limitation

$$SupplyPointEnergy_t \cdot \frac{60}{T_s} \leq SupplyPointPMax \;\; t \in [0, T-1]$$

- C1.5 Energy cannot be drained from EVs (no V2G support)

$$EVSEEnergy_{n,t} \geq 0 \;\; n \in [0, N-1] \;\; t \in [0, T-1]$$

- C1.6 Power flows towards EVs must not exceed EVSE nominal power

$$EVSEEnergy_{n,t} \cdot \frac{60}{T_s} \leq EVSEPower_n \;\; n \in [0, N-1] \;\; t \in [0, T-1]$$

Objective function

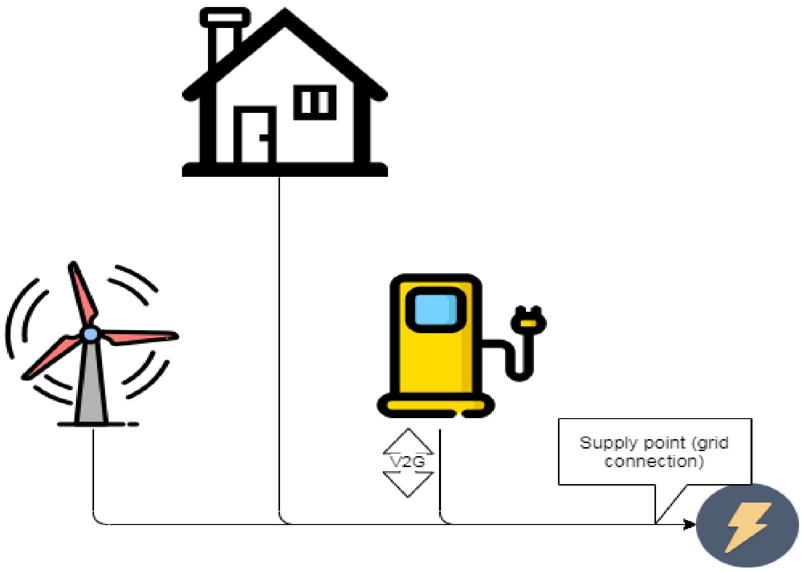
- O1 Minimise energy imported cost

$$minimize(\sum_{t=0}^{T-1} \max(0, SupplyPointEnergy_t) \cdot Price_t)$$

5.3.2 V2G schemes

This version of the model incorporates the of certain EVSEs to perform V2G (drain energy from the EVs)

Figure 10: Optimum charging profile based on V2G schemes



Changes respect to previous model

Inputs

- I2.1 EVSE nominal discharge power (kW). Set to 0 for those EVSEs with no V2G capabilities

$$EVSEDischargePower_n \; n \in [0, N-1]$$

Constraints

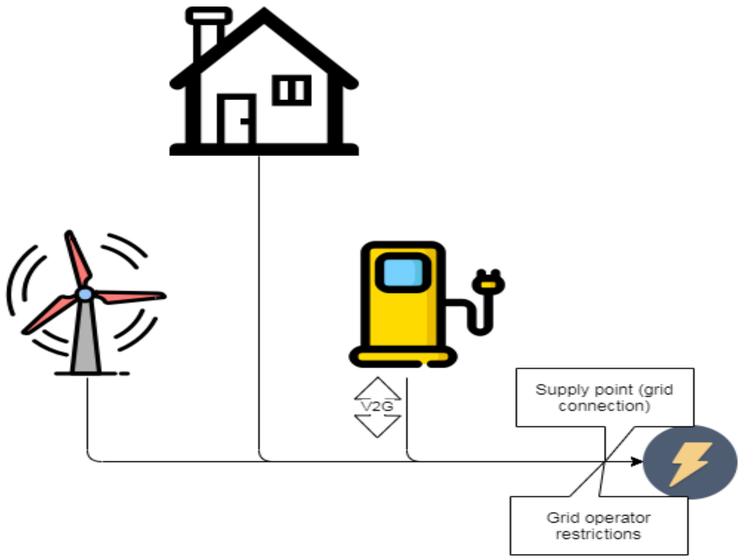
- ~~C1.5 Energy cannot be drained from EVs (no V2G support)~~ (removed)
- C2.1 Power flows discharging from EV must not exceed EVSE discharge power

$$EVSEEnergy_{n,t} \cdot \frac{60}{T_s} \geq EVSEDischargePower_n \;\; n \in [0, N-1] \;\; t \in [0, T-1]$$

5.3.3 Support to the grid

This version of the model incorporates the possibility of integrating support operations to the grid. These support operations consist of modifications on the supply point power flow limit (either upper, allowing greater demand, or lower, imposing demand limitations) provided by the grid operator (so-called *flexibility orders*).

Figure 11: Optimum charging profile based on support to the grid



Changes with respect to the V2G model

Inputs

- I3.1 Flexibility orders (kW) provided by grid operators. Those are interpreted as offsets over the maximum power at the supply point (usually the contracted power)

$$Flexibility_t\ t \in [0, T-1]$$

Constraints

- ~~C1.4 Power flow at supply point must not exceed limitation~~ (removed)
- C3.1 Power flow at supply point must not exceed the limitation, considering allocated flexibility

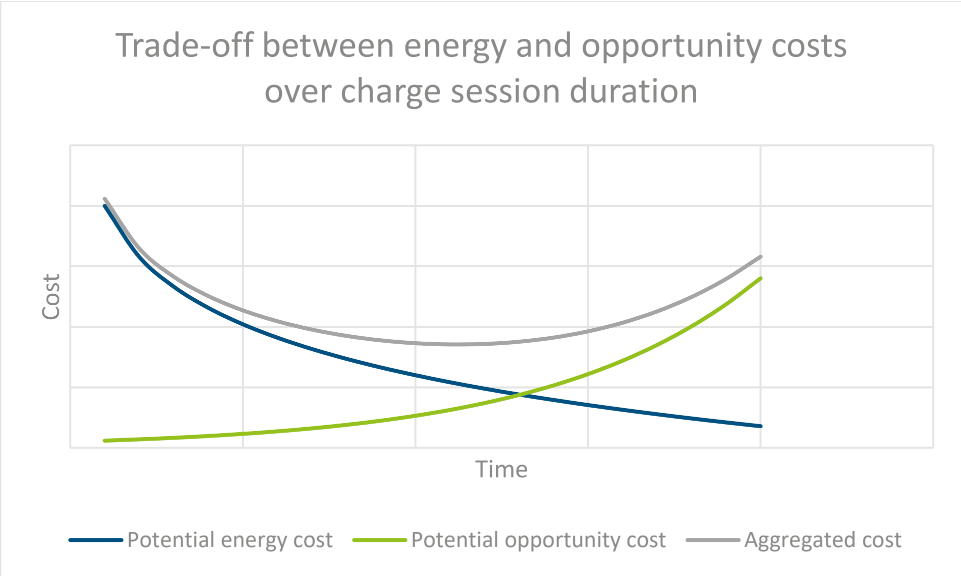
$$SupplyPointEnergy_t \cdot \frac{60}{T_s} \leq (SupplyPointPMax + Flexibility_t)\ \ t \in [0, T-1]$$

5.3.4 Trade-offs between smart-charge benefits and long-lasting charging sessions

Previous models include an inherent effect that is contrary to the ultimate business objectives of CPOs. By only considering the energy cost in the objective optimisation, an awkward phenomenon occurs: long-lasting charging sessions are encouraged, since those provide more flexibility to CPOs to modulate the energy delivery, and therefore are associated with more potential cost savings.

Even though this is true strictly speaking, the model so far omits the consideration that a CPO faces an opportunity cost for every new charge session that cannot be supplied due to the lack of free charging points. This cost increases with the duration of the active sessions.

Figure 12: Opportunity cost



By introducing an opportunity cost component to the objective function, the optimisation result will no longer encourage long-lasting charging sessions, pushing charging sessions to finalise at early stages, where a trade-off is reached between both types of cost..

Changes respect to v3 model

Inputs

- I4.1 Number of slots an EVSE has been occupied prior to the execution of the optimisation (time the charge session has taken place so far, measured in *slots*)

$$PreviousSlots_n \; n \in [0, N-1]$$

- Opportunity cost faced per duration of the charge session (linear cost, explore feasibility and more complex formulas – exponential?) (€/slot)

$$OpportunityCost$$

Objective function

- ~~O1 Minimise energy imported cost~~ (removed)
- O4 Minimise aggregated (energy imported + opportunity) costs

$$minimize(\sum_{t=0}^{T-1}(\max(0, SupplyPointEnergy_t) \cdot Price_t + \sum_{n=0}^{N-1}(PreviousSlots_n + t) \cdot OpportunityCost))$$

5.4 Charging profile communication

Previous sections document the procedures to report SMAC the data that can be taken into account in order to achieve the optimal charging profile for the charging transactions, as well as the definition of the algorithms inside the product backend that perform the optimisation.

Once the charging profile is calculated, the last step regarding SMAC workflow refers to reporting this data to the CPO, which is managing the charging transaction. This procedure follows the OCPI specification, which states the SCSP reports to CPO the charging rate limit for a period of time for an ongoing charging transaction. The communication between both parties is centralised by INCAR.

SMAC role in the smart charging scenario ends when the CPO receives the charging profile. In order to apply the charging profile received from SMAC, the CPO system must send an order to the corresponding charging station. This final step pertains entirely to the CPO, as their systems manage directly the charging posts.

6. Conclusions

In this deliverable, the work performed in the framework of task T4.2 has been presented.

Task 4.2 focuses on the analysis of the different requirements and usage scenarios defined by the WP1 as well as the list of use cases that need to be addressed by SMAC services. From this information, interfaces with the target users of the applications and their workflow with all elements, including backend components, have been identified.

Additionally, this document presents the formal specification of the proposed module to be included in the OCPI specification. This module will allow reporting the relevant data that a smart charging service provider can take into account for the calculation of the optimal charging profiles.

Knowing the set of data that can be reported to the system, it is possible to design the SMAC algorithms based on a linear optimisation model, which is able to perform the calculation of the optimal charging profiles depending on the amount of reported smart charging inputs.

The specifications described in this deliverable will be the main basis for the development of the smart charging tool in T4.3.

Acronyms

Acronym	Meaning
D	Deliverable
T	Task
USER-CHI	Project Title: innovative solution for USER centric CHarging Infrastructure
SMAC	Smart Charging Tool
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
SoC	State of Charge
V2G	Vehicle to Grid
CPO	Charge Point Operator
INCAR	Interoperability, Charging and Parking Platform
EMSP	Electromobility Service Provider
OCPI	Open Charge Point Interface
SCSP	Smart Charging Service Provider
WP	Work Package

References

[1] A. Martín, "Design and Specification of interoperability and roaming services," 2020.

[2] [Online]. Available: https://www.greenflux.com/ev-charging-software/ev-smart-charging/.

[3] E. R. Foundation, "Open Charge Point Interface," 2020.

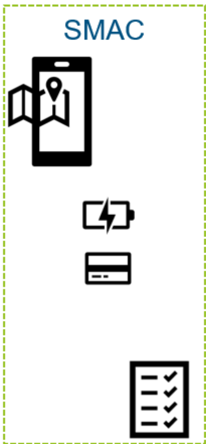
Annexes

Excerpt of D1.2: SMAC Usage Scenarios

SMAC Usage Scenario for Barcelona

Scenario 1. Barcelona

Usage Scenario 1. Interoperability according to user group CPOs



SMAC: Smart Charging Tool to dynamically optimise the power supplied to the Charging Points.

Objective: Allow an intelligent and dynamic management of demand based on this analysis, which will allow CPOs to manage in a more efficient and economical way the energy supplied at their charging points by, at the same time, improving the service to the end-user.

User's profile: Charging Point Operators. CPOs using the SMAC website interface

- End-users participate selecting options offered by the smart charge

User's sample: 5-10 technical managers in AMB charging point network.

Resources: a station with several charging points (ultra fast, quick, normal) in the AMB charging network (end 2021), INCAR platform and INCAR app including SMAC utilities.

CPO: AMB

EMSP: AMB

Scenario 1. Barcelona
Usage Scenario 1. Interoperability according to user group AMB Infrastructure

SMAC can offer different smart charging strategies according to the user profiles and the total power available:

- At night, users stay all the night parked, and the charging station could offer long period of charge at medium or low power.
- And just the opposite during the day: users stay for a while and need high power.

The table shows an example: different charging strategies could be possible.

SMAC strategy	CHAdeMO DC	COMBO DC	Mennekes	Mennekes	Mennekes	Mennekes	Mennekes	TOTAL
day	25-50 kW max. 30 min	25-50 kW max. 30 min	3 kW max. 2 h	7 kW max. 2 h	3 kW max. 2 h	7 kW max. 2 h	3 kW max. 2 h	75 kw
night	25 kW max. 2 h	25 kW max. 2 h	7 kW max. 2 h	3 kW max. 8 h	3 kW max. 8 h	3 kW max. 8 h	3 kW max. 8 h	75 kW

Scenario 1. Barcelona
Usage Scenario 1. Interoperability according to user group USER PROFILE: CPOs

User story D (i):

Anna is a charging point' manager in AMB.

She is one of the five-ten people participating in SMAC assessment, a tool including smart grid integration services, RES electricity supply, reduction of grid impact and demand management.

Anna is managing charging points. She receives a document to use the SMAC tool (tasks and tutorial), and one link to perform assessment activities.

She is now exploring the Smart Charging features in the online website (statistics, series, data access, ..), in order to offer both the maximum power and the high-quality level in this charging stations. At night, the charging stations should offer long period of charge at medium or low power, and just the opposite during the day: short period of charge at high power. Anyway, Anna is able to define the restrictions and the required level of service for each charging point considering the user preferences (charge as fast as possible, as cheap as possible, 80% battery in 3 hours, in 8 hours…). She will receive from SMAC the charging profile for each user when he books the point.

Pedro, an INCAR user with a subscription with AMB, books a charging pole and selects a low cost charging. The INCAR app sends a request to the system, and SMAC generates a charging profile which is sent back to the CPO system and then to the charging point.

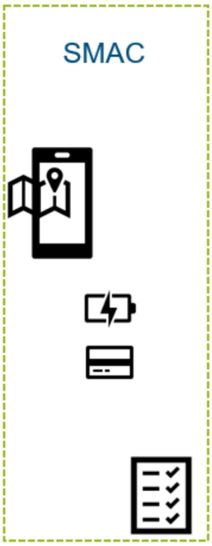
Scenario 1. Barcelona
Usage Scenario 1. Interoperability according to user group USER PROFILE: CPOs

Monitoring & Assessment

- A mobility planner of the city council needs to evaluate the performance of the electromobility in the city, so she wishes to display information offered by INCAR E-Mobility Dashboards.
- In a first moment, the elements of the electromobility in the city (e.g. EVSEs) that have a geographical position are displayed in a map. Hanna clicks an element in the map and details about it are displayed
- Hanna wants to check historical data about charging operations performed during a concrete period of time for the urban mobility planner information. In this case, the user introduces the dates of interest and selects the metrics he want e.g. detailed charging transactions such as power supplied, CO2 equivalent emissions, time spent on charging processes, bookings information such as counting, average duration or frequency, etc.

SMAC Usage Scenario for Budapest

Scenario 5. Budapest
Usage Scenario 17. PROFESSIONAL PROFILE



SMAC: Smart Charging Tool to dynamically optimise the power supplied to the Charging Points.

Objective: Allow an intelligent and dynamic management of demand based on this analysis, which will allow CPOs to manage in a more efficient and economical way the energy supplied at their charging points by, at the same time, improving the service to the end-user.

User's profile: Charging Point Operators. CPOs using the SMAC website interface

- End-users participate selecting options offered by the smart charge

User's sample: 5-10 technical managers in Budapest charging point network.

Resources: Budapest charging network (> 150 poles), INCAR platform and SMAC app.

CPO: Budapest

EMSP: Budapest

Scenario 5. Budapest
Usage Scenario 17.
PROFESSIONAL PROFILE

User story (i):

Hanna is a charging point' manager in Budapest mobility area. She is one of the five-ten people participating in SMAC assessment, a tool including smart grid integration services, RES electricity supply, reduction of grid impact and demand management.

Hanna is managing charging points. She receives a document to use the SMAC tool (tasks and tutorial), and one link to perform assessment activities.

She is now exploring the Smart Charging features in the online website (statistics, series, data access, …), in order to offer both the maximum power and the high-quality level in this charging stations. At night, the charging stations should offer long period of charge at medium or low power, and just the opposite during the day: short period of charge at high power. Anyway, Hanna is able to define the restrictions and the required level of service for each charging point considering the user preferences (charge as fast as possible, as cheap as possible, 80% battery in 3 hours, in 8 hours…). She will receive from SMAC the charging profile for each user when he books the point.

Emma, an INCAR user without subscription, books a charging pole and selects a low cost charging. The INCAR app sends a request to the system, and SMAC generates a charging profile which is sent back to the CPO system and then to the charging point.

Scenario 5. Budapest
Usage Scenario 17.
PROFESSIONAL PROFILE

User story (ii):

Another day, Hanna receives a requirement asking for information related to electromobility performance. In order to answer the requirement, she employs the INCAR utilities for professionals (related to INCAR Monitoring & Assessment, see the section below).

After the use of SMAC, a validation screen is activated and Hanna answers the asked metrics (related to utility, ease to use, satisfaction and promote intention). Finally, Hanna answers an online questionnaire. She really likes the information and the settings functions for CPOs, but she doesn't find out how to filter the data and to export it for exploitation.

At the end, the demo site must be able to provide 5-10 successful stories like this.

Scenario 5. Budapest
Usage Scenario 17.
PROFESSIONAL PROFILE

Monitoring & Assessment

- A mobility planner of the city council needs to evaluate the performance of the electromobility in the city, so she wishes to display information offered by INCAR E-Mobility Dashboards.
- In a first moment, the elements of the electromobility in the city (e.g. EVSEs) that have a geographical position are displayed in a map. Hanna clicks an element in the map and details about it are displayed
- Hanna wants to check historical data about charging operations performed during a concrete period of time for the urban mobility planner information. In this case, the user introduces the dates of interest and selects the metrics he want e.g. detailed charging transactions such as power supplied, CO2 equivalent emissions, time spent on charging processes, bookings information such as counting, average duration or frequency, etc.

SMAC Usage Scenario for Rome

Scenario 4. RSM
Usage Scenario 13.
PROFESSIONAL PROFILE

SMAC

SMAC – Use of the Smart e-Mobility Dashboards

Objective: To analyse smart grid integration services, RES electricity supply, reduction of grid impact and demand management. Validate service configuration. Display real time and historic information for the management of the e-mobility.

User's profile: ENELX Mobility and ENELX Italy technicians

User's sample: 10 technical managers in ENELX charging point network.

Resources:
- Corso Francia Charging Station.
- Via Cristoforo Colombo Hub

CPO: ENELX Mobility

EMSP: ENELX Italy

Scenario 4. RSM
Usage Scenario 13.
PROFESSIONAL PROFILE

User story (i):

Eva is a charging point' manager in ENELX. She is one of the ten people participating in SMAC assessment, a tool including smart grid integration services, RES electricity supply, reduction of grid impact and demand management.

Eva is managing charging points Via Cristoforo Colombo Hub. Currently, she is facing some problems during the night with the new charging points added in an existing station.

She is now exploring the Smart Charging features in order to offer both the maximum power and the high-quality level in this large charging station. At night, the charging station should offer long period of charge at medium or low power, and just the opposite during the day: short period of charge at high power.

With SMAC tool, she is able to define the restrictions and the required level of service for each charging point considering the user preferences (charge as fast as possible, as cheap as possible, 80% battery in 3 hours, in 8 hours…). She will receive from SMAC the charging profile for each user when he books the point.

Eva receives a document to use the SMAC tool (tasks and tutorial), and one link to perform assessment activities. Secondly, she explores the CPO dashboards: statistics, series, data access, …

Scenario 4. RSM
Usage Scenario 13.
PROFESSIONAL PROFILE

User story (ii):

Another day, Eva receives a RSM requirement asking for information related to performance electromobility. In order to answer the requirement, she employs the INCAR utilities for professionals (related to INCAR assessment/validation, see the section below).

After the use of SMAC, a validation screen is activated and Eva answers the asked metrics (related to utility, ease to use, satisfaction and promote intention). Finally, Eva answers an online questionnaire. She really likes the information and the settings functions for CPOs, but she doesn't find out how to filter the data and to export it for exploitation.

At the end, the demo site must be able to provide 10 successful stories like this.

Scenario 4. RSM
Usage Scenario 13.
PROFESSIONAL PROFILE

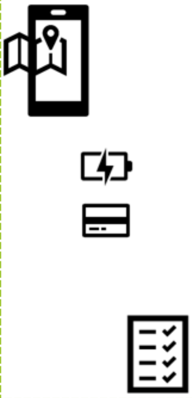
Monitoring & Assessment:

- A mobility planner of the city council needs to evaluate the performance of the electromobility in the city, so she wishes to display information offered by INCAR E-Mobility Dashboards.
- In a first moment, the elements of the electromobility in the city (e.g. EVSEs) that have a geographical position are displayed in a map. Anne clicks an element in the map and details about it are displayed
- Anne wants to check historical data about charging operations performed during a concrete period of time for the urban mobility planner information. In this case, the user introduces the dates of interest and selects the metrics he want e.g. detailed charging transactions such as power supplied, CO2 equivalent emissions, time spent on charging processes, bookings information such as counting, average duration or frequency, etc.

SMAC Usage Scenario for Turku

Scenario 3. Turku
Usage Scenario 9
PROFESSIONAL PROFILE

SMAC



SMAC: Smart Charging Tool to dynamically optimise the power supplied to the Charging Points.

Objective: Allow an intelligent and dynamic management of demand based on this analysis, which will allow CPOs to manage in a more efficient and economical way the energy supplied at their charging points by, at the same time, improving the service to the end-user.

User's profile: Charging Point Operators. CPOs using the SMAC website interface

- End-users participate selecting options offered by the smart charge

User's sample: 5-10 technical managers in Turku charging point network.

Resources: 22 kW AC chargers (6) & Solar energy & Battery system

CPO: Turku Energia

ESMP: IGL

Scenario 3. Turku
Usage Scenario 9
PROFESSIONAL PROFILE

User story (i):

Anne is a charging points' manager in Turku Energia.

She is one of the five-ten people participating in SMAC assessment, a tool including smart grid integration services, RES electricity supply, reduction of grid impact and demand management.

Anne is managing the six smart charging station located in the VASO housing building, in the area of Pääskyvuorenrinne. She receives a document to use the SMAC tool (tasks and tutorial), and one link to perform assessment activities.

She is now exploring the Smart Charging features in the online website (statistics, series, data access, …), in order to offer both the maximum power and the high-quality level in this charging stations. At night, the charging stations should offer long period of charge at medium or low power, and just the opposite during the day: short period of charge at high power. Anyway, Anne is able to define the restrictions and the required level of service for each charging point considering the user preferences (charge as fast as possible, as cheap as possible, 80% battery in 3 hours, in 8 hours…). She will receive from SMAC the charging profile for each user when he books the point.

Aino, a resident in VASO housing building, books a charging pole and selects a low cost charging. The INCAR app sends a request to the system, and SMAC generates a charging profile which is sent back to the CPO system and then to the charging point.

Scenario 3. Turku
Usage Scenario 9
PROFESSIONAL PROFILE

User story (ii):

Another day, Anne receives a City of Turku requirement asking for information related to performance electromobility. In order to answer the requirement, she employs the INCAR utilities for professionals (related to INCAR monitoring&assessment, see the section below).

After the use of SMAC, a validation screen is activated and Anne answers the asked metrics (related to utility, ease to use, satisfaction and promote intention). Finally, Anne answers an online questionnaire. She really likes the information and the settings functions for CPOs, but she doesn't find out how to filter the data and to export it for exploitation.

At the end, the demo site must be able to provide 5-10 successful stories like this.

Scenario 3. Turku
Usage Scenario 9
PROFESSIONAL PROFILE

CITY OF TURKU

Monitoring & Assessment

- A mobility planner of the city council needs to evaluate the performance of the electromobility in the city, so she wishes to display information offered by INCAR E-Mobility Dashboards.
- In a first moment, the elements of the electromobility in the city (e.g. EVSEs) that have a geographical position are displayed in a map. Anne clicks an element in the map and details about it are displayed
- Anne wants to check historical data about charging operations performed during a concrete period of time for the urban mobility planner information. In this case, the user introduces the dates of interest and selects the metrics he want e.g. detailed charging transactions such as power supplied, CO_2 equivalent emissions, time spent on charging processes, bookings information such as counting, average duration or frequency, etc.

Excerpt of D1.3: SMAC Legal and Technical Requirements

ID	Description	Type
SMC_001	CPO platforms must implement OCPP 1.6 or 2.0 for smart charging operations	Operational requirements
SMC_002	From different smart charging inputs SMAC must calculate the optimal charging profile for a charging session. The calculated charging profile will be reported to CPOs, but it is responsibility of CPOs to execute smart charging operations	The scope of the product
SMC_003	CPOs must implement OCPP 2.0 for V2G operations	Operational requirements
SMC_004	SMAC services will not be available for charging stations not involved in INCAR platform	Operational requirements
SMC_005	CPOs must inform if their EVSEs support smart charging operations	Operational requirements
SMC_006	EMSPs should inform about users default charging profile in order to consider it as smart charging input	Operational requirements
SMC_007	SMAC should specify a prioritization for the identified smart charging inputs	Operational requirements
SMC_008	CPOs should inform about locations restrictions such as the maximum power the EVSEs can provide	Operational requirements
SMC_009	Energy prices should be aspect of smart charging	The scope of the work
SMC_010	SMAC should implement Planned start-charging time for slow charges	The purpose of the product
SMC_011	SMAC must include an assessment of V2G impact on battery life	Operational requirements
SMC_012	SMAC should give an indication of the advantages of a smart charging operation vs generic charging operation (less electric load, charging costs, battery life prolongation, ...) to CPO and end user	Functional and data requirements
SMC_013	SMAC should list the technical necessities (or products) to make smart charging operations implementable.	Users of the product
SMC_014	SMAC must implement OCPI 2.2 modules related with Smart Charging Service Providers (SCSP)	Operational requirements

SMC_015	SMAC needs to consider interoperability requirements deriving from Art. 4 (4) AFI-Directive (compatibility with Type 2 power sockets)	Legal requirements
SMC_016	Requirements deriving from European / national calibration and measurement laws need to be taken into account for different billing models	Legal requirements
SMC_017	SMAC needs to enable ad-hoc charging processes, as required by Art. 4 (9) AFI-D	Legal requirements
SMC_018	SMAC should consider national regulation on the topic of V2G - if existing	Legal requirements
SMC_019	SMAC should work without INCAR	Operational requirements
SMC_020	SMAC must consider the DSO as possible demander of V2G operations.	The purpose of the product
SMC_021	Could include information on EV being charged/requesting to charge	Functional and data requirements