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User centric charging infrastructure for electric vehicles - Guidelines for operators to implement advanced smart charging and management strategies

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European foreword

This CEN Workshop Agreement has been developed in accordance with the CEN-CENELEC Guide 29 “CEN/CENELEC Workshop Agreements – A rapid prototyping to standardization” and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by a Workshop of representatives of interested parties on 2023-11-29, the constitution of which was supported by CEN following the public call for participation made on 2023-07-07. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

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Introduction

This document presents results generated in the USER-CHI project, a research and innovation project funded under European Union's program Horizon 2020, aimed at unlocking the massive potential of electromobility in Europe, from a user-centric perspective.

Following an operator driven innovation approach and considering the driver preferences to charge an electric vehicle in a public/semi-public area, the project has developed a smart charging tool based on the OCPI 2.2.1 last version protocol. The new Charging Profile module included in the OCPI 2.2.1 brings a valuable functionality in the direction from the algorithm provider to the operator, however it is not sufficient to obtain the best profile for the best implementation of smart charging strategies. The document intends to give some recommendations at this regard.

The market's adoption of the latest protocol versions is recognized to be sluggish, resulting in a delay in unlocking the full potential of smart and bidirectional charging capabilities. This situation would be avoided if the market embraces new protocol versions earlier. Fruit of the group work composed of the technology providers and the electromobility operators from different countries, and the different uses cases tested in five European cities, this document proposes the smart charging architecture that the different electromobility actors should follow if wanting to offer smart charging services in their charging infrastructure through the last OCPI protocol versions.

In addition, also some keys and recommendations are given to i) implement the automated payments that will help to the operators to manage all the economic flows between the different actors and ii) implement the roaming hub mode that will result in eliminating a lot of red tape (peer-2-peer contracts) and in increasing their offer in other networks and therefore increasing the possibility to get more charges making the installation more cost-effective.

The guidelines for operators presented in this document aim to cover the following aspects, such as:

— Smart charging as a service.

— Methodology and guidelines for operators to implement smart charging through OCPI protocol.

— Open Architecture ensuring system interoperability, transparency and openness.

— Uses cases.

— Recommendations for protocols and systems.

— Software requirements and recommendations to implement smart charging through OCPI protocol.

— Other key point to take into consideration:

  o Roaming via hub.

  o Automated payments.

  o Other functionalities.

Besides software solutions offered by the OCPI protocol allowing for V2G and load balancing, alternative hardware-based solutions are also in development or already available. Alternative solutions comprise, amongst others, autonomous connection devices (ACD), AVP-guided parking systems, and inductive and conductive charging solutions. With connection options to all available sides of the vehicle.

1 Scope

This document provides guidance in terms of smart charging, interoperability and payment and accounting processes among the different actors of the electromobility domain (Charging Point Operators-CPO, eMobility Service Providers-eMSP, micro-CPOs and Smart Charging Service Providers-SCSP), to set up a series of homogenous strategies and methodologies that facilitate the implementation of advanced functionalities in the electromobility operator systems.

The provided smart charging strategies will help the operators to optimize their energy-related costs, enabling a better utilization of renewable energy sources and allowing their participation as active actors in the smart grid management, both as participants of implicit strategies and explicit campaigns.

This document also includes the framework to be followed by the operators in the implementation of the smart charging as a service and for the implementation of automation of the economic compensations among all involved actors.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
(automated) electric Vehicle Service Equipment
(a)EVSE
automated (a) or manually operated Electric Vehicle Supply Equipment consisting of a single charger or combination of charger and automation connecting facility, allowing for conductive (AC & DC) or inductive charging

3.2
charging point operator
CPO
subject holder of the exploitation rights of the charging point infrastructure

3.3
distribution system operator
DSO
the entity responsible for distributing and managing energy from the generation sources to the final consumers.

The operating managers (and sometimes owners) of energy distribution networks, operating at low, medium and, in some member states, high voltage levels (LV, MV). Transmission grids transport large quantities of high (and extreme high) voltage (HV, EHV) electricity across vast distances, often from large power plants to the outskirts of large cities or industrial zones, where it is transformed into lower voltages distributed to all end-users through the distribution network. Over-head and underground cables leading to the homes or business are operated by DSOs.

3.4
electric vehicle
EV
vehicle that can be powered by an electric motor that draws electricity from a battery and is capable of being charged from an external source. An EV includes both a vehicle that can only be powered by an electric motor that draws electricity from a battery (BEV, all-electric vehicle) and a vehicle that can be powered by an electric motor that draws electricity from a battery and by an internal combustion engine (PHEV, plug-in hybrid electric vehicle)

3.5
electromobility service provider
EMSP
virtual operator that can act as a third party providing value-added services to the user of electric vehicles

3.6
micro-CPO
entities with interest in installing and offering charge points to potential users, but missing capacity to manage them appropriately (e.g., restaurants, supermarkets, malls). Electromobility is not their primary business

3.7
quality of service
QoS
global effect of the quality of operation of a service that determines the degree of satisfaction of a user of said service

3.8
renewable energy sources
RES
renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. RES include wind, solar, aerothermal, geothermal, hydro, ocean energy sources, biomass and the biodegradable fraction of waste

3.9
smart charging service providers
SCSP
the SCSP is the connecting factor which is in direct contact with the local grid operator and, via the national grid operator, is also able to communicate with the energy market

3.10
state of charge
SoC
level of charge of an electric battery relative to its capacity. SoC is usually expressed as percentage (0% = empty; 100% = full)

3.11
time-of-use tariff
ToU tariff
time-based billing structure under which the rate charged for each unit of electricity consumed can vary depending on the time of the day

3.12
vehicle-to-grid
V2G
technology that enables energy to be pushed back to the power grid from the battery of an electric vehicle (EV). With V2G technology, an EV battery can be discharged based on different signals — such as energy production or consumption nearby

4 Smart charging

4.1 General

The definition of smart charging according to CEN-CENELEC-ETSI and Eurelectric is when charging an EV can be externally controlled (i.e., “altered by external events”), “allowing for adaptive charging habits, providing the EV with the ability to integrate into the whole power system in a grid- and user-friendly way. Smart charging must facilitate the security (reliability) of supply while meeting the mobility constraints and requirements of the user.”

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

The management takes place shfiting the energy load among the chargers, however there are already solutions (e.g., aEVSE and AVP) in the market that will be able to change the connector between different cars in an autonomous way increasing, even more, the efficiency of the charging process.

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 charged, 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, and are interesting from a point of view of holistic infrastructure energy management optimization.

These smart charging features provide benefits to different stakeholders involved in electromobility scenario. For example, it will make the infrastructure more cost effective for the CPO’s and the charge cheaper for the end user.

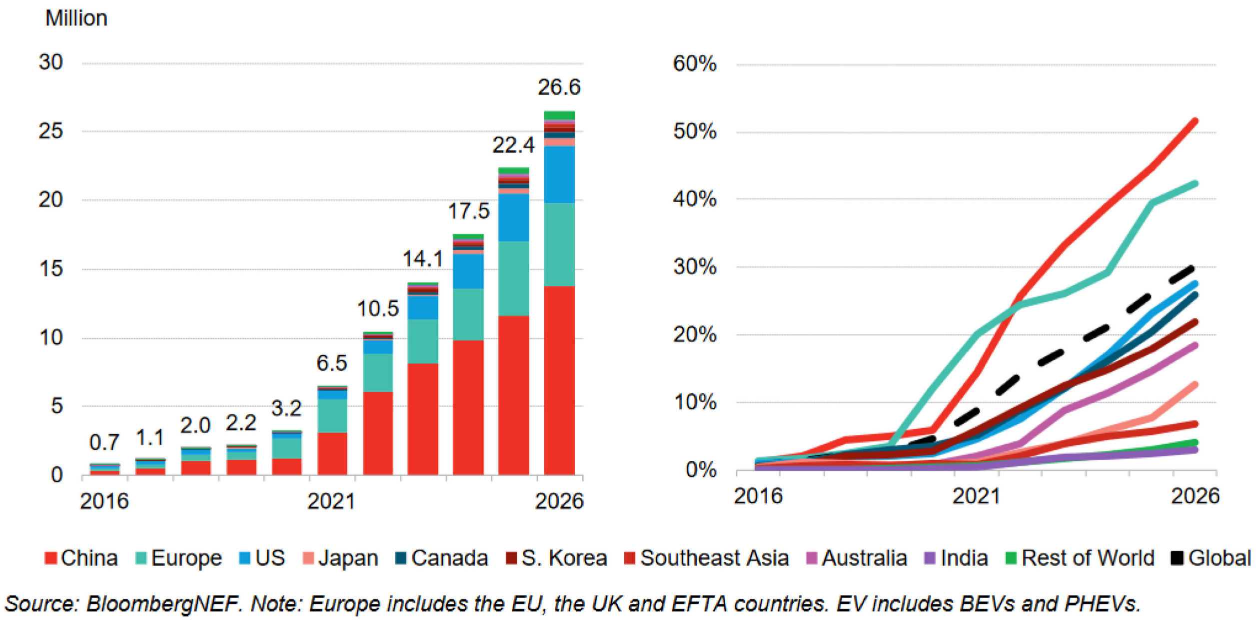

Figure 1 — Global near-term passenger EV sales and share of new passenger vehicle sales by market til 2026. Source: (BloombergNEF, 2023)

According to the latest forecasts (Figure 1), the number of passenger EVs will rise to 100 million in 2026 (27 million passenger EVs on the road at the end of 2022), and EVs will represent nearly third of all passenger cars sold globally by 2026 (14% at the end of 2022). EV charging infrastructure and, more specifically, smart charging management will therefore play a vital role in the upcoming years. Comparison between the forecasted EV fleet and the current number of electric vehicles on European[1)] roads (around 8 million at the end of 2022), gives an indication of 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, avoiding overloading the grid.

4.2 Objectives

In order to provide the appropriate context to the benefits and objectives of smart charging features, those are split in two environments, depending on the corresponding actor benefitting from those objectives.

4.2.1 Micro Environment

In the microenvironment, the actors mainly targeted by smart charging management systems are found. The first objective of those systems in order to gain visibility and acceptance needs to be the optimization of the costs faced by the charging infrastructure owners – typically CPOs or tertiary infrastructure managers/owners, even though the increasing number of private home chargers makes it also interesting to keep domestic users targeted already in the design of those services. Two main costs related to the electricity supply need to be addressed:

— Energy costs (cost per kWh): those are the direct costs that can be minimized by smart charging systems, by considering ToU tariffs and/or local RES generation in the design of the charging profiles in order to shift load towards periods with lower prices and higher local generation availability.

1) EU27 + UK, Norway, Iceland, Switzerland, Turkey, Liechtenstein.

— Capacity costs (cost per kW): those are indirect costs that can be minimized by smart charging systems that take into consideration the time available to complete a charging session (thus potentially lowering the power required to charge the EV) and the typical usage profile of a set of chargers (e.g., finding a proper and well-known balance between QoS – probability of fulfilling one customer's energy requirements in time - and contracted capacity).

Even though other secondary costs may also be taken into consideration (e.g., design of charging profiles that take into consideration storage depreciation and minimize battery degradation).

On the other hand, for those actors offering charging services in public spaces, it may be more relevant to pursue the maximization of the usage and availability of the (a)EVSEs; i.e., charging as fast as possible in order to free the (a)EVSE as fast as possible, and keep the (a)EVSE available for further customers.

In the end, the main objective pursued by these actors is reducing operating costs, which will increase competitiveness of those actors (by transferring these savings towards end users).

4.2.2 Macro Environment

In the macro environment, the main identified actor to benefit from smart charging strategies are the Distribution System Operators (DSOs) (ENTSO-E, 2021) (RAP, 2022). Even though distributions grids are typically oversized nowadays, adoption of new EV charging infrastructure will pose a significant extra pressure to those grids. DSOs are particularly interested in delay the need of investing in network reinforcement. Towards this objective, smart charging management systems can help by increasing the capacity of the grids to host EV charging infrastructure, where capacity is understood as the capability to provide EV charge sessions with appropriate levels of QoS without performing network reinforcement investments. This can be achieved by the autonomous capabilities of smart charging management systems to effectively reduce the supply point capacity requirements (in terms of power), which can potentially benefit from the introduction of effective communication between charge infrastructure managers and DSOs.

The DSO will also play a relevant role in the Flexibility markets regulated by the Electricity Market Regulation (2019/943) and Electricity Market Directive (2019/944). The last advances promoted the reform of those regulation and directive (DSO Entity, 2023). However, still no standardised market products for flexibility exist in Europe (smartEn / Delta-E, 2020). In addition, there is no discrimination by type of resource, i.e., the protocol to participate in the flexibility market will not be different for the electric vehicles. All the resources should be registered in the NEMO market platform. So that, there is space for the development of a particular protocol for the electric vehicle flexibility resource. Opening local flexibility markets will induce smart charging services to respond.

4.3 Analysis of the existing strategies for smart charging implementation

With regards to the technical aspects of the smart charging strategies, main available solutions can be classified in two groups:

4.3.1 Hardware-based solutions

Hardware-based solutions usually involve the installation of additional physical assets next to the EV chargers. These assets are for example load balancers, which mainly measure the power flows on the supply point, communicate with the chargers in order to understand their current status (i.e., charging or idle and supplied powers) and, following their configuration, send back the setpoints to the chargers in order to keep a proper share of the available power. Some chargers already embed this functionality and are able to effectively provide load balancing among their different connectors.

4.3.2 Software-based solutions

Software-based solutions basically pursue the same objectives but move the logic to a software module of the corresponding EV charging infrastructure management system (typically a CPO backend). In this case, therefore, all communication exchanges between the elements are no longer local, and take place over a communication network with a remote server.

4.3.3 Comparative analysis

Even though both approaches are functionally similar, the main difference relies in the location where the module executing the load balancing or smart charging is deployed, and therefore in the necessity or not of incurring in the costs of installation of an additional hardware (for those cases where this functionality is not embedded in the charger). More in detail, there are differences in the following terms, which benefit one or the other solution:

— Communication latency and robustness: the closer the elements are physically located, the better the communication required between the elements will work. Quality of the communication can be measured in terms of latency and robustness. While local area networks employed by hardware-based solutions are fast, offer low latencies and highly availability, networks involving remote communication (usually over mobile networks) present worst indicators in this respect.

— Frequency of updates: directly related with the previous point, having better communications allows higher rates of measurements and communication exchanges. This can be effectively used by hardware-based load balancers to provide fine-grained charging profiles, adaptable to fast changes in the context (e.g., adapting in real-time to demand or generation peaks). In this sense, charging profiles provided by software-based solutions tend to be coarser, and less capable of reacting to fast-changing contexts.

— Installation costs: on the other hand, hardware-based solutions involve incurring in investment of physical assets and their installation, costs that are minimized in the case of software-based solutions that operate over already existing communication channels (i.e., no extra, or lower-cost investment is required).

— Upgradability and configurability: in general terms, software-based solutions are easier to fix and upgrade, and extra features can be built without impacting the physical installation (i.e., at lower costs).

— Software-as-a-Service (SaaS): software solutions embracing SaaS architectures can scale up and provide smart charging features to a number of different chargers, locations and even tenants, therefore taking advantage of the economies of scale to become a more competitive solution.

4.4 Smart Charging as a service

In order to foster smart charging adoption at a wide level, proposed solutions must be technically and economically scalable. Following main characteristics are therefore claimed desirable for future developed smart charging management solutions.

4.4.1 Software-based solutions and SaaS architectures

Even though this kind of solutions do not come without cons, software-based solutions are proven to scale better both technically and economically, and the operative tasks involved in their deployment, configuration, application of fixes, upgrades and adaptability to include new functionalities are easier and more affordable to tackle when compared with hardware-based solutions. While hardware-based solutions still have their market niche (facilities in need of fine-grained profiles that react rapidly to changes in the context), true wide adoption of smart charging features will be provided by software-based solutions. In particular, solutions able to provide services to different locations and tenants simultaneously (as those design under the SaaS architecture principles) will make a difference by benefitting the most from economies of scale.

4.4.2 Based on open standards

Smart charging solution providers must be able to design products that can work together with a variety of charge point vendors. This has benefits for all actors involved, which prevent vendor-locking issues, and fosters competitiveness in these markets. In order to make this possible, all communications and interactions need to happen over well-defined open standards:

— Open: specifications must exist under proper formats and must be publicly available. This facilitates the adoption of those protocols in the industry, enables the creation of a community around those protocols which maintains, fixes and enhances them, even facilitating the appearance of automated assessment tools to help companies validate the compliance of their own implementations.

— Standard: specifications must be accepted by the international community, which provides safety in terms of continuity and validity of the specifications and the solutions that are based on those.

4.4.3 Key role of Smart Charging Service Providers (SCSP)

As complexity of smart charging scenarios arises, there is place to a new actor in the electromobility domain which is specialized in the calculation of optimum charging profiles. This new actor is called Smart Charging Service Provider (SCSP), and will contribute to foster the adoption of this strategies in already existing and new charging infrastructures. The main objective pursued by SCSPs is to provide CPOs the ability to implement smart charging strategies over the Charging Points under their control, by giving them the possibility to outsource the calculation of those optimum profiles to a third-party.

Its primary target is therefore to facilitate the access of any CPO to this feature, by including a seamless integration of their services into existing CPOs backends. This integration will mainly handle:

— The communication of the required inputs to the SCSP with the agreed frequency and resolution, in order to allow SCSP to gain understanding of the current context of the chargers to be optimized.

— The reception and application of the optimum charging profiles calculated and communicated by the SCSP to the CPO.

In order to have complete control of the context to be optimized, SCSPs must offer to their customers (CPOs) the appropriate interfaces to allow further configuration of the elements and characteristics of the installation (e.g., contractual limits to the power availability, capability or not of performing V2G operations, existence of additional uncontrolled demand or local RES generation that must be taken into consideration, among others), as well as access to the appropriate set of KPIs (profiles produced, amount of demand shifted through smart charging operations, achieved savings…).

4.5 Architecture

In this document, a scalable architecture based on existing open protocols is proposed, in which all relevant points addressed in this chapter have been considered.

The presented architecture is built around the clear differentiation of four electromobility roles, which mainly interoperate by means of OCPI 2.2.1-based communication.

— Electro Mobility Service Provider (EMSP) handles the access of EV drivers to the charging infrastructure.

— Charging Point Operator (CPO) manages the charge points and offers EV charging services. In the proposed architecture, management of smart charging is outsourced in favor of the SCSP.

— Smart Charging Service Provider (SCSP) specializes in calculating appropriate charging profiles on behalf of CPOs, according to the information facilitated.

— Electromobility HUB (HUB) provides scalability to the solution by enabling one-to-many contractual relationships among the partners.

As depicted in Figure 2, this architecture can operate by combining two of the new features present at OCPI 2.2.1, namely the *Platform via Hub* topology and the *ChargingProfiles* module.

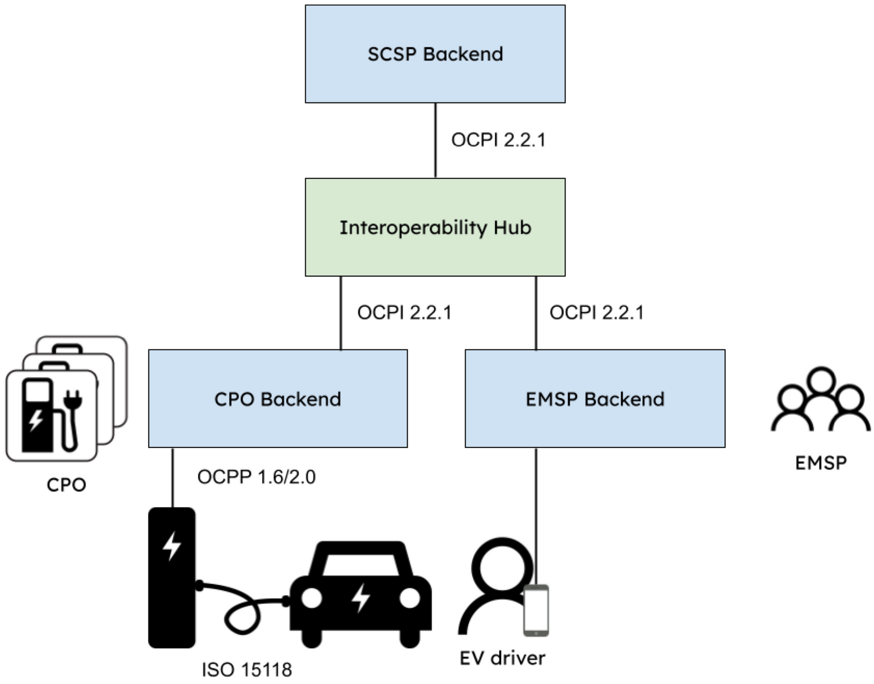

Figure 2 — Proposed architecture for smart charging

The main interactions involved are depicted in Figure 3 and Figure 4.

In summary, main flow happens between CPO, HUB and SCSP. Whenever a CPO gets updated information about an ongoing session (either a new charge session is started, stopped or Charge Point reports updated Meter Values), this information needs to be sent to the SCSP in order to keep an updated view on what happens at the charger or chargers, and let it decide whether an update of the Charging Profiles is applicable. This happens by exchanging Session object updates over OCPI 2.2.1. If it is the case, updated Charging Profiles are sent back from the SCSP to the CPO.

On the other hand, OCPI 2.2.1 additionally facilitates end users (in this case, EV drivers through the corresponding interface provided by the EMSP) to communicate their charging preferences to the involved parties. In this case, EV drivers can communicate their requirements (basically, the energy needed and the available time for the charge session to take place) to the EMSP. These requirements are further transmitted to the CPO in the form of an OCPI 2.2.1 *ChargingPreferences* object, which is finally retransmitted from the CPO to the SCSP in order to be taken into account in the charging profile optimization. SCSP responds with a confirmation or a rejection of the charging preferences, e.g., in those cases where set preferences cannot be met, thus allowing end users to be informed about this result, and all involved partners to react and reuse this information appropriately.

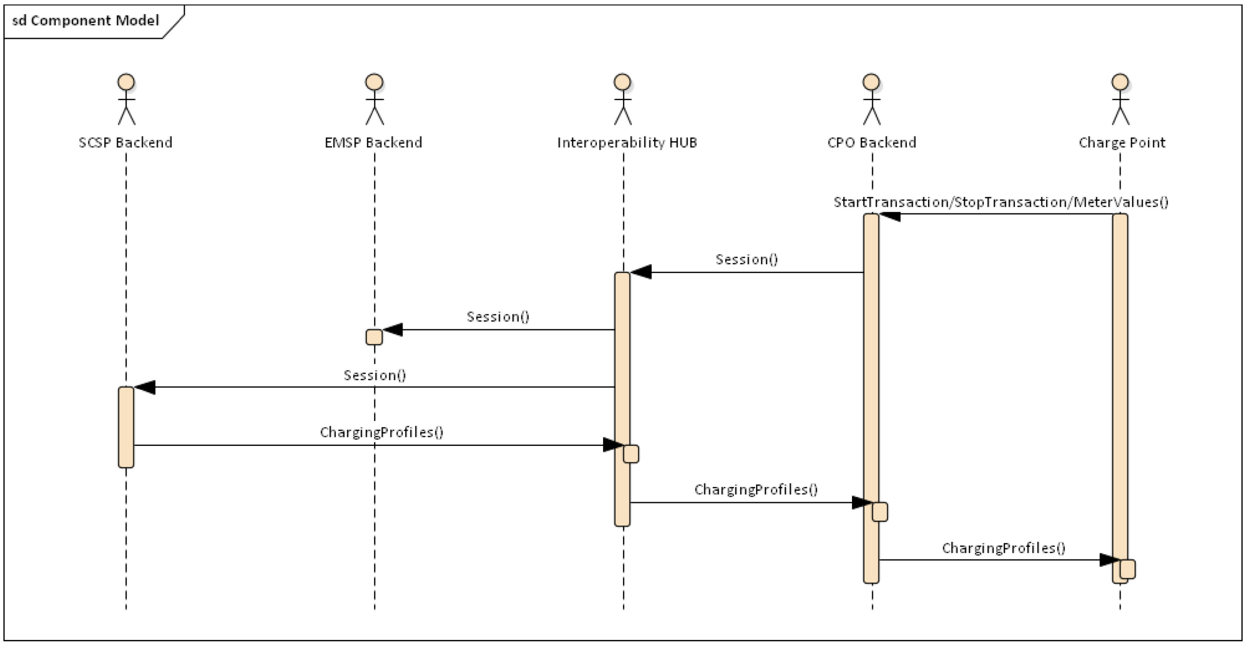

Figure 3 — Basic CPO — HUB — SCSP flow

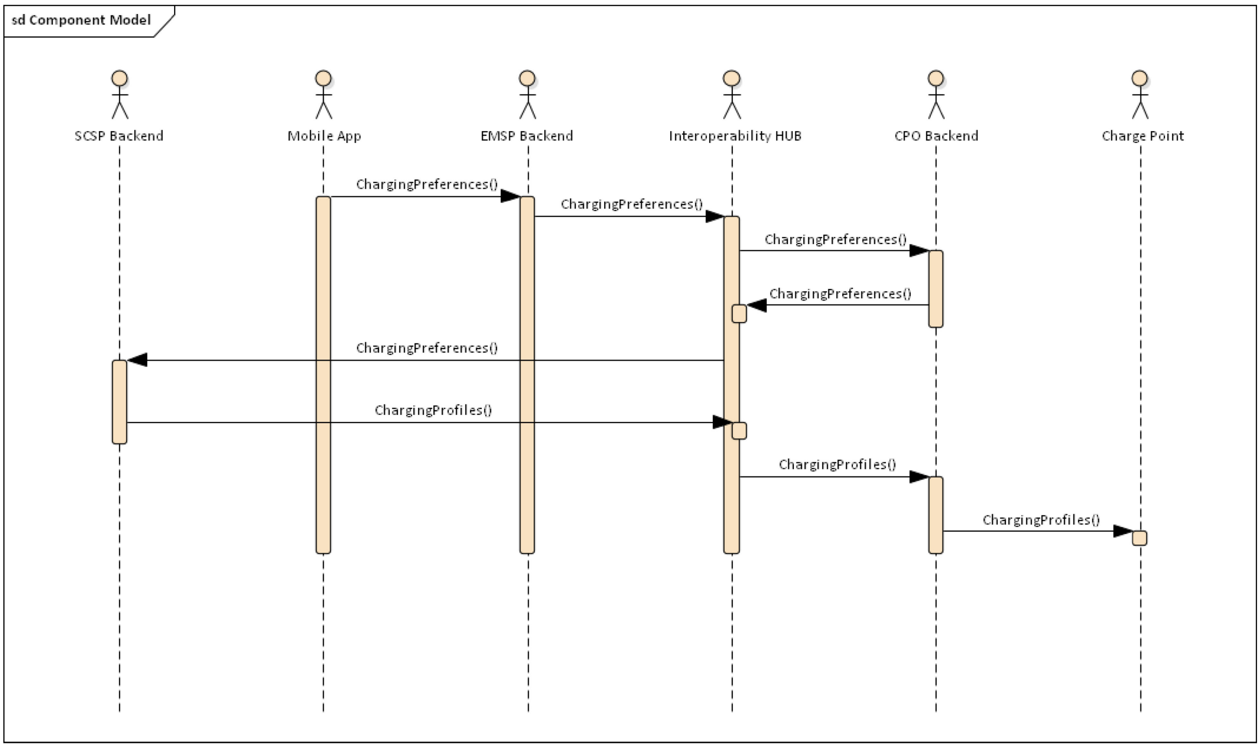

Figure 4 — Basic EMSP — HUB — CPO — SCSP flow

4.6 Protocols

While the architecture proposed so far in the previous section successfully handles the interactions between the actors to send purely related data about ongoing sessions and produced charging profiles, OCPI 2.2.1 fails at defining further communication channels to allow SCSPs to get further relevant information of the context, which would provide added value to the calculated charging profiles (e.g., capacity of the supply point, measurements of related uncontrolled demand or RES generation…). It is therefore advisable that OCPI 2.2.1 (and other protocols addressing the same functionality) evolve and include standardized means to exchange the data that is produced in a typical self-consumption installation that includes EV charging infrastructure.

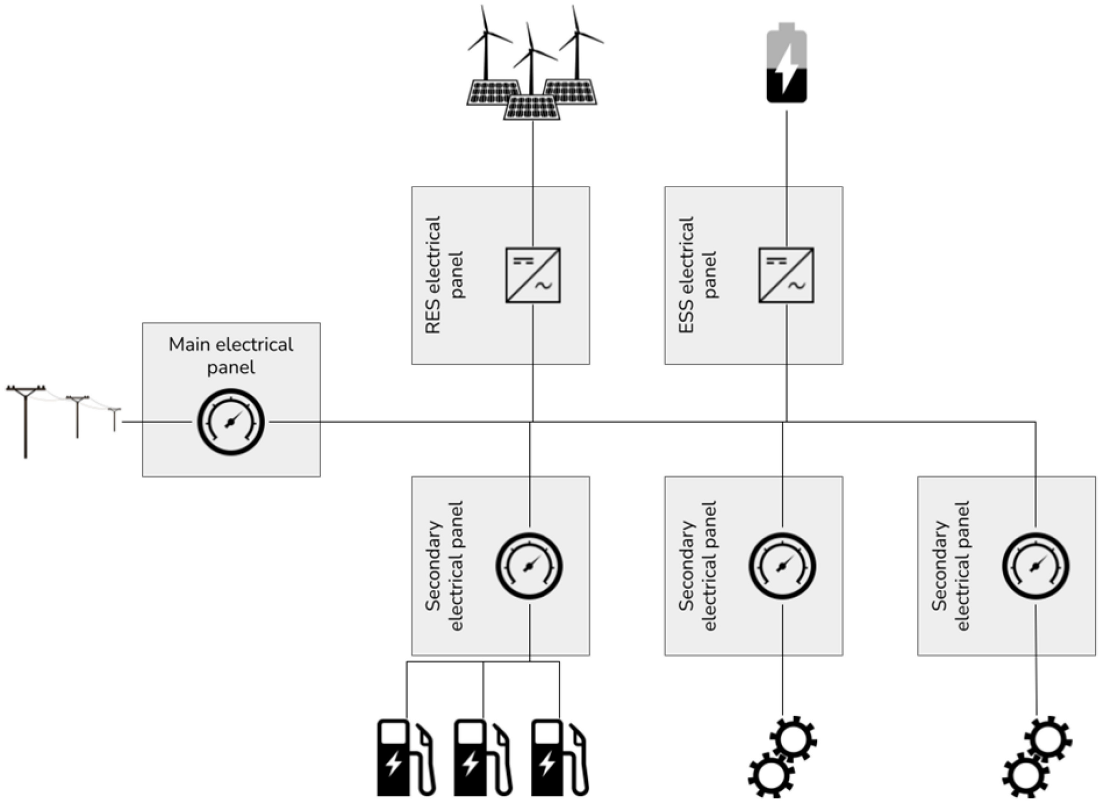

Figure 5 — Typical self-consumption facility including EV charging infrastructure

Data produced in or related to such environments, that is relevant for the calculation of optimal Charging Profiles, includes:

— Maximum available capacity at supply point (active power), e.g., supply point contracted capacity.

— Maximum reverse flow capacity at supply point (active power), which may have an impact in scenarios presenting RES or V2G-capable chargers.

— Number, identity and nominal characteristics of all EVSEs to be managed together (i.e., under the same supply point).

— Price of the electricity (relevant for infrastructures with Time of Use (ToU) or dynamic tariff schemes).

— Measurements of uncontrolled demand and/or generation.

— Forecasted values for the uncontrolled demand and/or generation.

— Extra temporary limitations to the capacity availability (e.g., extra limitations imposed by the DSO as a result of participation of local flexibility markets).

4.7 Guidelines for operators to implement smart charging through OCPI protocol

As exposed in previous sections, the presented architecture, whose main targets are scalability and facilitating access to smart charging strategies to all actors of the electromobility domain, is built around the specification of the OCPI 2.2.1 protocol. In this context, Table 1 details the corresponding OCPI module implementation that would need to be undertaken by the main actors (CPO, SCSP) in order to adhere to the proposed architecture.

Most implementation recommendations follow the recommendations already contained within the OCPI 2.2.1 specification document, but with special hints at particular points:

— Hub Client Info module: this implementation is only required if communication is routed via an Interoperability Hub, as recommended by the proposed architecture of this document.

— Locations module: while not strictly mandatory, it is considered a wealth channel of inputs towards SCSP. By implementing this module, SCSPs can gain access to a number of details about the EVSEs which are relevant to the calculation of the optimum smart charging profiles (i.e., electric characteristics and limits of the corresponding connectors).

— Session’s module: sessions module is necessary to communicate data about new and ongoing charging sessions from the CPO to the SCSP. A special remark in this context is that, since SCSP is only interested in the electrical measurements related to the ongoing session, any information about the driver (e.g., cdr_token data) should be removed from the data exchange.

— Smart Charging Optimization module: as exposed in previous section, OCPI 2.2.1 specification lacks a proper mechanism to transmit additional required data from CPOs towards SCSPs. In order to cover this gap, future versions of this protocol (and similar protocols) should define new modules allowing communication of any potential input required by SCSPs in order to make it possible to calculate optimum profiles. *Smart Charging Optimization* module consists of a new custom module, out of the specification, built on top of the OCPI 2.2.1 specification and allowing exchange of these data items in a similar manner to other modules.

Table 1 — OCPI modules implementation per role

Modules	CPO	SCSP
CDRs		
Charging Profiles	Receiver	Sender
Commands		
Credentials	Both	Both
Hub Client Info	Receiver*	Receiver*
Locations	Sender**	Receiver**
Sessions* **	Sender	Receiver
Tariffs		
Tokens		
Versions	Both	Both
Smart Charging Optimization******	Sender	Receiver

4.7.1 Required inputs per use case

The flexible architecture of the OCPI protocol and the integration of the SCSP role makes it possible to dynamically deal with the variety of use cases.

Smart charging strategies can be configured to accomplish a number of potential use cases. In this section, the most popular use cases are listed, together with a comprehensive set of input requirements per use case. This table will help operators willing to adopt smart charging strategies to get a better understanding on the kind of data they should be able to measure and transmit in order to achieve their objectives.

In general, in order to enable any kind of smart charging strategy, the following set of common inputs will be required, which can be either static, or communicated through existing OCPI specifications if they are dynamic:

— Capacity of the supply point: maximum active power (kW) available for the installation (considering EV chargers and extra demand).

— Limits to the reverse flow capacity at supply point (kW).

— Nominal charge power per EVSE/connector, as well as any combined limitation for the charge points (kW).

— Nominal discharge power per V2G-capable EVSE/connector (kW).

— Stationary storage characteristics (if applicable), including capacity (kWh) and maximum charge and discharge powers (kW).

In particular, the dynamic inputs required by smart charging that will vary depending on the objective pursued may include:

— Energy price (currency/kWh) and its timely evolution (e.g., in case of dynamic or ToU tariffs).

— Measurements of the uncontrolled demand (demand connected to the same supply point but not controlled by the smart charging mechanisms) (kWh/time slot, e.g., 15 minutes readouts).

— Measurements of the RES generation (generation fed behind the meter to the same supply point) (kWh/time slot, e.g., 15 minutes readouts).

— Uncontrolled demand forecasts in the short-term (next hours) (kWh/time slot, e.g., 15 minutes).

— RES generation forecasts in the short-term (next hours) (kWh/time slot, e.g., 15 minutes).

— Flexibility requests imposed by external agents (e.g., DSO, aggregator), which basically consist of additional temporary limits to the capacity of the supply point (kW/time slot, e.g., 15 minutes).

— Driver charge preferences, which may include information about capacity of the EV battery (kWh), current state of charge (%), desired state of charge (%) and indications on the timeframe the EV will remain plugged to the charger. This input is mostly relevant in public charging spaces

— Fleet charge requirements, which may include information about arrival of the vehicles to the depot, required departure times, and estimated energy requirements per vehicle (kWh). This input is mostly relevant in private charging spaces, in synergy with Fleet and/or Depot Management Systems.

— Stationary storage state of charge (%, periodic readouts).

Different combinations of the data items presented above may be used to enable a set of use cases for smart charging, namely:

— Dynamic load balancing: capacity of the system to dynamically assign different active power setpoints to the active chargers in order to keep quality of service (i.e., manage to complete the charge sessions in-time) while keeping the total demand of the system under the given constraints.

— Reduce capacity requirements: reduce the overall active power needed to complete the charge sessions while keeping a certain level of quality of service (i.e., the total amount of charge sessions successfully completed above a certain percentage of the total).

— Energy cost-driven smart charging: use smart charging strategies to manage load-shifting towards periods where cost of the energy is more affordable.

— RES-driven smart charging: use smart charging strategies to manage load-shifting towards periods where availability of local RES generation is available or more likely.

— Self-consumption optimization: load-shifting of the EV chargers demand considering their integration in a facility as a whole, which includes uncontrolled demand, local RES generation and (potentially) stationary storage, with the objective of maximize the use of the local generation. May be combined with an energy cost-driven strategy to additionally pursue energy cost reduction on top of the self-consumption strategy.

— Flexibility management: use smart charging strategies to analyse the potential to shift the demand of the EV chargers (flexibility, which depends on the timeframe the EVs remain plugged to the charger and their energy requirements), offer this flexibility to external agents (e.g., aggregators or local flexibility markets) and react to their signals (i.e., indications to shift load at certain periods in time).

Table 2 — Smart charging use cases and dynamic inputs

Use case	Energy price	Uncontr demand	RES gen.	Uncontr demand forecast	RES gen. forecast	Flex. reqs.	Driver charge prefs.	Storage SoC
Dyn. load balancing							x	
Reduce capacity reqs							x	
Energy cost-driven smart charging	x						x	
RES-driven smart charging	(x)		x		(x)		x	(x)
Self-consumption optim.	(x)	x	x	(x)	(x)		x	(x)
Flex. mgmt.		(x)	(x)	(x)	(x)	x	x	

5 Interoperable open charging infrastructure

5.1 General

An open charging infrastructure in which all market participants can participate on a non-discriminatory basis and the various systems within the e-mobility market can work together is required to make charging electric vehicles as convenient as refueling is today for ICE vehicles.

Interoperability ensures that assets and systems from different manufacturers can work together, accelerating the adoption of EVs, reducing costs, and encouraging innovation.

European legislation has so far mostly focused on hardware interoperability. As early as 2014, the European Union proposed standard socket outlets for both AC and DC charging stations with the publication of the alternative fuels infrastructure directive[2)].

Furthermore, significant strides were made in achieving software interoperability through the introduction of the alternative fuels infrastructure directive. This directive, implemented in 2020 and onwards, mandated that EV drivers should have the ability to charge their vehicles at any publicly accessible charging station within the European Union without the need to enter into a contract with the corresponding EMSP. This move aimed to enhance user-centricity by granting EV drivers unrestricted, transparent, and fair access to databases containing information such as the geographical locations of charging stations and the prices set by charging station operators.

However, achieving software interoperability can present challenges, particularly when EMSP does not simultaneously function as a CPO (i.e., it does not operate its own charging infrastructure) or when the EV driver charges their vehicle at a charging station owned by a different CPO. Addressing this issue, roaming, a vital aspect of interoperability, comes into play. By establishing communication protocols that allow the software systems of the CPO and EMSP to communicate effectively, roaming ensures that essential data such as user identification and the amount of energy charged can be seamlessly exchanged (Sustainable Transport Forum, 2020).

Today, in the market, there are different roaming protocols addressing interoperability around the four electromobility roles presented in section 4: OCHP, OICP, eMIP and OCPI. These four protocols are all published online and freely accessible. Each of them has their own characteristics and is governed by a different group of interest.

— **Open Clearing House Protocol (OCHP)** is developed by the joint venture of Dutch foundation ElaadNL and smartlab Innovationsgesellschaft mbH from Germany and managed by the roaming hub e-clearing.net. OCHP is published under the MIT license, which allows for free distribution and modification. Smartlab/ElaadNL have the sole authority to make edits to the standard as such. A yearly membership fee applies to all partners on the e-clearing.net roaming platform. Since 2017, in order to facilitate maximum partner autonomy and freedom of choice, e-clearing.net introduced additional services to offer the following OCPI modules to their partners as an alternative to OCHP: Credentials, Tokens, Locations, CDRs, Tariffs, Sessions, Commands.

— **Open InterCharge Protocol (OICP)** was created by Hubject in 2013. Hubject's stakeholders are the BMW Group, Daimler, Bosch, EnBW, Enel X, Siemens, Volkswagen, and Innogy – all German parties. OICP can be used to communicate within Hubject's platform, enabling communication between EMSPs and CPOs. Unlike the other roaming platforms, Hubject does not only offer a technical connection between parties but also a contractual framework for roaming. OICP is publicly available at no cost and without registration. Along with OICP, Hubject also offers ad-hoc payment solutions.

2) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0094

— **eMobility Interoperation Protocol (eMIP)** was designed and is managed by GIREVE, an integrated platform founded by EDF, Renault, CNR and Caisse des Dépôts. It is most widely used in France. eMIP supports both roaming via the GIREVE platform and peer-to-peer connections, with functionalities including: Providing charge point and sessions information, Authorisation, Billing, Platform monitoring.

eMIP lets CPOs and EMSPs add any sort of data messages or identification methods, thus allowing new features to be implemented quickly, without the need for repeat protocol version updates.

Also, eMIP is the only protocol that supports a charge point search module, which allows EMSPs to retrieve a list of charge points located in a given geographic area and fulfilling a set of charging criteria (e.g., connector type).

— **Open Charge Point Interface protocol (OCPI)** was developed by eViolin, an association of Dutch charge point operators and mobility service providers, in collaboration with ElaadNL, a group of major Dutch grid operators. OCPI is currently managed and maintained by the EVRoaming Foundation (Netherlands Knowledge Platform for Public Charging Infrastructure (NKL)), which is a collaboration of trade organizations, governmental bodies and research institutes.

OCPI supports both peer-to-peer (P2P) and roaming hub connections. In P2P roaming, CPOs and EMSPs have direct bilateral connections via which they exchange data. Meanwhile, in hub-based roaming, a CPO or EMSP can access many roaming partners via a single, standardised connection.

Currently, OCPI is the **most widely used roaming protocol in Europe** thanks to its broad feature range and highly open approach to development.

OCPI is the only protocol with a smart charging module.

The following tables shows the comparison between the different protocols.

	OCHP v1.4 & OCHP Direct v.02	OICP v.2.2	eMIP v0.7.4	OCPI v2.2
Managed by	e-clearing.net	Hubject	GIREVE	NKL (to be transferred to OCPI management board)
Managing organisation is not at the same time the operator of an associated roaming hub	No (but hub role is non-exclusive)	No	No	Yes
Download documentation and protocol free of charge	Yes	Yes	Yes	Yes
Download documentation and protocol without registration	Yes	Yes	No	Yes
Public copyright license	MIT license	Creative Commons ShareAlike 4.0 International	None	Creative Commons Attribution-NoDerivatives 4.0 International
Protocol is open source[15]	Yes	Yes	No	No
Organization of user feedback	Yes	Yes	Yes	Yes
Open community-based development	No	No	No	Yes (OCPI community)

Figure 6 — Various governance aspects of the roaming protocols. Source: (van der Kam & Bekkers, 2020)

Although OCPI is becoming the most used protocol and the protocol officially used by many Governments (e.g., used in the National Access Point for charging infrastructure in Spain), their main drawback is the lack of support for the implementation by the operators. This document intends to cover this gap offering recommendations and architecture for smart charging implementation.

	OCHP	OICP	eMIP	OCPI
Core functionalities				
Identification of EV users	+	+	+	+
Authorization of charging sessions	+/0	+	+	+
Recording charging session information	+/0	0	+/0	+
Billing	+	+	+	+
Data protection	*	*	*	*
Architectural openness	-	-	+	+
Use of options	0	0	-	+
Scalability	*	*	*	*
Quality control				
Conformance with other standards	+/0	+/0	+/0	+/0
Support to assess quality of implementation	+/0	+	+	0
Support to assess quality of data input	+	+	+	+
Open standard				
Transparency	+	+	0	+
Openness	0	0	-	Current: +/0 Future: +
Impartiality and consensus	0	-	-	+/0
Effectiveness and relevance	+	+	+	+
Coherence	+	+	+	+
Development dimension	0	0/-	0/-	0
Business model agnostic	+	0	0	+

Figure 7 — Evaluation on how the protocols score to the proposed design principles. + indicates high, 0 indicates medium, - indicates low. * indicates that assessing these aspects is out of scope of this document. Source: (van der Kam & Bekkers, 2020)

5.2 Analysis of the current situation

Nowadays, a number of barriers exists causing significant inconvenience to EV drivers and reluctancy to adopt electromobility as the principal private transport means among society, namely:

— multiple/different e-roaming platforms with proprietary protocols,

— different authentication and billing technologies such as RFID cards, smartphone apps, QR codes and means of payment resulting in difficulties to access charging stations,

— payments between CPOs and EMSPs when a user using a charging point operated by one CPO wants to charge at charging point owned by another CPO (e.g., on a long trip or journey),

— legal barriers on the local, regional, and national level.

Overcoming such barriers will lead to a better perception of the services provided and will foster adoption of electromobility. Interoperability platforms and mechanisms play their role in overcoming those, by providing, on one hand, potential access to a high number of charging infrastructure to EV drivers (regardless of their actual operator), and, on the other hand, higher visibility and access to a higher number of customers to CPOs. All in all, efforts required by entities both technically and legally, as well as the used pricing schemes, suppose in practical terms a barrier that discourages smaller entities from providing electromobility services.

5.3 Objectives

In general terms, future situation must facilitate scalability of the available and usable charging infrastructure. This necessarily implies opening the ecosystem to smaller entities, whose principal business will be unrelated to electromobility (e.g., restaurants, shops, hotels) but which are in position of offering higher number of chargers with wider geographical distribution. In this line, and in order to achieve a proper quality of service for EV drivers, the following desirable characteristics for the future have been identified:

— Interoperability platforms must offer one-to-many contracts (opposed to one-to-one contracts). In practical terms, this means that peer-to-peer relationships between CPOs and EMSPs should be discouraged in favor of relationships managed by interoperability HUBs, which regulate relationships and provide interoperability with the complete portfolio of partners through simpler contractual mechanisms that require less effort.

— Related to the previous point, interoperability HUBs should offer automated accounting, billing, and clearing mechanisms for the economic exchanges that happen between the partners, unifying and facilitating also the payment mechanisms available for EV drivers.

— Pricing schemes and onboarding processes should be simplified in order to allow smaller entities with high potential to offer EV charging services to become autonomous partners of such electromobility hubs (i.e., avoiding their need to outsource this management or partnership with a third-party CPO). In this sense, pay-per-use of implementation of fees that are proportional to the business volume are proven to be more attractive than regular fixed payments or onboarding fees.

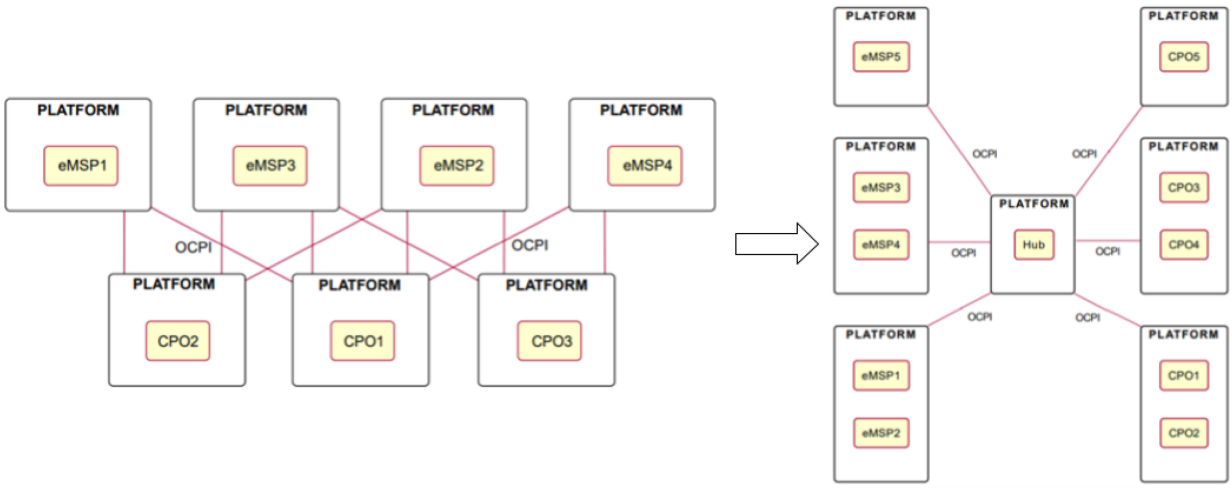

Figure 8 — Evolution of current towards recommended future interoperability topology. Source: (EVRoaming Foundation, 2021)

On the other hand, once the electromobility domain opens to smaller players, harmonization of different requirements coming both from classic actors (bigger CPOs or EMSPs) and new actors (smaller entities offering EV charging services, which at this document will be named micro-CPOs onwards) needs to be taken into account.

Bigger entities will typically:

— Offer electromobility services to their customers through their own managed apps or, in general, computer systems – where services offered by third-party partners through the interoperability HUB will be integrated.

— Offer added-value services on top of electromobility services (e.g., special EV charging prices as part of a wider customer loyalty program and having the possibility to pre-book a slot on the charging systems can give a shorter delay time in the charging time).

On the other hand, smaller entities will take advantage of:

— Potential existence of white-label apps offered by the interoperability HUB manager.

— Simplified contractual mechanisms, which include simple and fair pricing schemes and automated billing and clearing processes.

5.4 Architecture

The architecture proposed hereby takes into consideration all points from previous sections, and is consistent with the architecture proposed in section 4.4.

The presented architecture is built around the clear differentiation of four electromobility actors, which mainly interoperate by means of OCPI 2.2.1-based communication.

— Electro Mobility Service Provider (EMSP) handles the access of EV drivers to the charging infrastructure

— Charging Point Operator (CPO) are entities whose primary business consists in managing the charge points and offer EV charging services.

— Micro-CPOs (μCPO) are entities with interest in installing and offering charge points to potential users, but missing capacity to manage them appropriately (e.g., restaurants, supermarkets, malls). Electromobility is not their primary business.

— Electromobility Hub (HUB) provides scalability to the solution by enabling one-to-many contractual relationships among the partners.

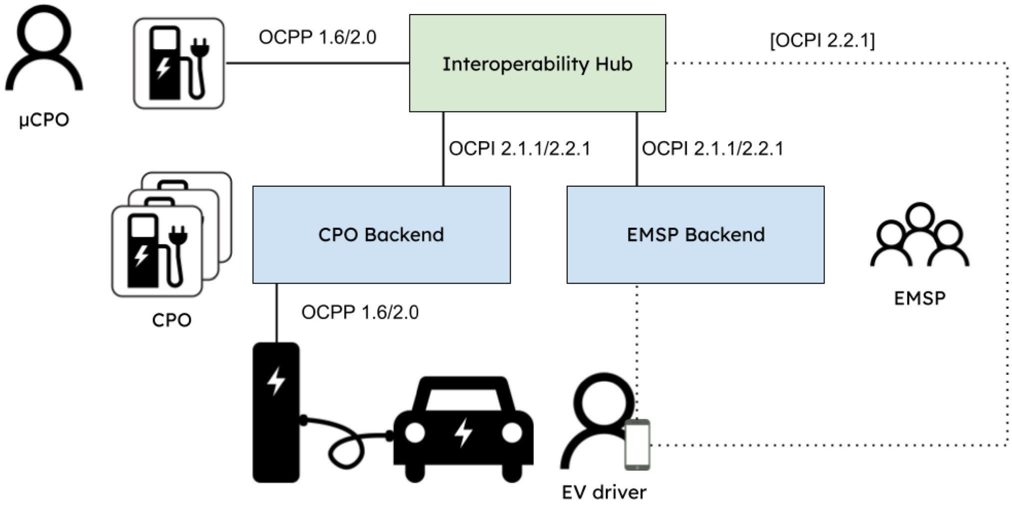

Figure 9 — Proposed architecture for interoperability

The main technical points of the architecture are:

— OCPI protocol in its most popular (2.1.1) and recent (2.2.1) versions are selected as the main channel for the communication exchanges between the involved partners (CPOs, EMSPs) through the HUB.

— In order to facilitate integration to µCPOs, HUB facilitates direct connection of their owned charging infrastructure via OCPP protocol, thus becoming their de-facto *CPO backend*, and automatically enabling making this charging infrastructure available and reachable to the rest of partners of the HUB.

— By design, already EMSP mechanisms to offer these services to their customers (e.g., custom apps) are still supported. Handling these mechanisms lies behind the EMSP Backend, which interfaces with the HUB (and the rest of partners) using a standardized OCPI-based communication.

— In addition, this design is open to the possibility of developing generic or white-label apps that communicate directly with the HUB in order to facilitate access to all the charging infrastructure offered by the corresponding partners. This app can be potentially used by casual drivers or adopted and integrated by µCPOs in their primary businesses. No specific protocol exists covering this communication, but a subset of the OCPI 2.2.1 specification has been proven to be suitable to implement this channel.

With regards to the business-related aspects of the interoperability HUB, following characteristics are advised:

— Facilitate onboarding of new partners (CPOs, µCPOs and EMSPs) by:

  - Offering a simple web-based interface to register and provide all necessary information, not only for technical integration (i.e., OCPI or OCPP related information), but also for payment management, billing and clearing (e.g., legal company information, bank account details, credit card details).

  - Avoid first-time or regular fixed fees, in favor of pay-per-use and fees proportional to business volume (e.g., fixed plus percentage over the total amount of a charging operation).

— Support pay-per-use and popular payment methods towards end users.

— Automate billing and clearing processes among partners of the HUB.

Towards facilitating these objectives interoperability HUB can be integrated with third-party services specialized in payment-processing and ecommerce.

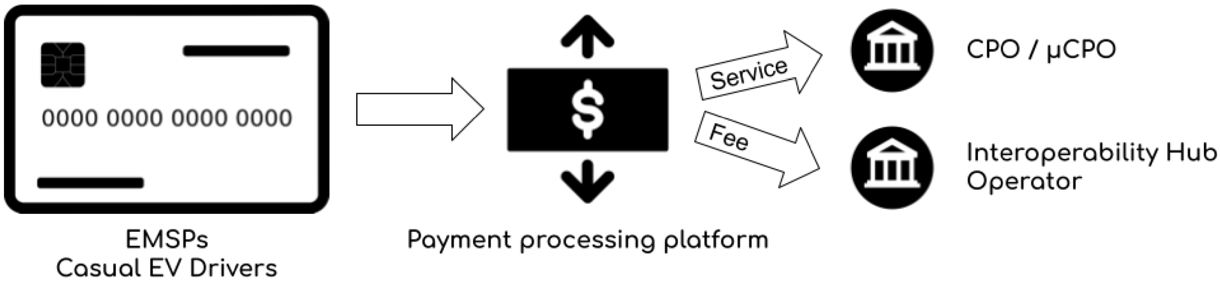

Figure 10 — Overview of money flows managed by an interoperability HUB using external Payment Processing Platform

Bibliography

[1] USER-CHI PROJECT. Innovative solutions for USER centric CHarging Infrastructure. https://www.userchi.eu/

[2] *EU market monitor for demand-side flexibility 2020*. smartEn / Delta-E. 2020

[3] OUTLOOK E.V. *Bloomberg Finance*. 2023, **L** p. 2023

[4] *Observations on: Electricity Market Design Proposals*. DSO Entity, Brussels, 2023

[5] *ENTSO-E Position Paper: Electric Vehicle Integration into Power Grids*. ENTSO-E. 2021.

[6] *OCPI 2.2.1. Open Charge Point Interface*. EVRoaming Foundation. 2021

[7] *Open Charge Point Interface 2.2.* (n.d.). Retrieved from https://evroaming.org/app/uploads/2019/10/OCPI-2.2.pdf

[8] *The time is now: smart charging of electric vehicles*. RAP, Brussels, 2022

[9] *Recommendations for public authorities on: procuring, awarding concessions licenses and/or granting support for electric recharging infrastructure for passenger cars and vans*. Brussels. Sustainable Transport Forum. 2020.

[10] VAN DER KAM. M., & BEKKERS, R. *Comparative analysis of standardized protocols for EV roaming. Report D6.1 for the evRoaming4EU project*. evRoaming4EU. 2020

[11] REGULATION (EU) 2019/943 Of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast)

[12] DIRECTIVE (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast)

[13] DIRECTIVE 2014/94/EU of the European Parliament and of the Council on the deployment of alternative fuels infrastructure

[14] Series EN ISO 15118, *Road vehicles — Vehicle to grid communication interface*

[15] IEC 62746-10-3:2018, *Systems interface between customer energy management system and the power management system — Part 10-3: Open automated demand response — Adapting smart grid user interfaces to the IEC common information model*

[16] Series EN IEC 63119, *Information exchange for electric vehicle charging roaming service*

[17] Series EN IEC 63110, *Protocol for management of electric vehicles charging and discharging infrastructures*