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Enhanced booking services for electric mobility

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Abstract The transition from conventional vehicles to electric vehicles dictates the design and development of user-centric charging solutions aiming to facilitate the accessibility to as well as the usability of the charging network and improve the user's charging experience. This paper presents the design of booking services to facilitate electric vehicle users to reserve a charging solution based on their charging preferences and needs. The objective is to develop interoperable booking services for static and mobile charging stations and battery swapping ones which will enhance the communication of user's reservation requests to the Charging Point Operator, reduce the time wasted by EV users searching unoccupied charging stations and, consequently, improve EV user's charging experience.

Keywords: Smart Charging, Electromobility, Smart Mobility

1. Introduction

In recent years, the pressing need of improving the quality of the air in urban areas encourages the research of new mobility solutions able to reduce the pollutant emissions and the traffic congestion [5]. The related literature deals with the important problem of distributing and scheduling the vehicles to the stations. Considering the possibility of utilizing modern ICT tools and smart stations centralized and distributed approaches are [1], [2]. In particular, [1] proposes a distributed ICT infrastructure to enable the intelligent exploitation of energy resources in order to minimize the EV charging times, interconnecting wireless and wired communication technologies. Moreover, in [2] each vehicle chooses its own charging profile for the following day according to a price profile updated in order to guide their behavior.

Ease of usability and accessibility to the charging network is the key challenge towards promoting e-mobility concept in urban environment. Additionally, the interfacing between the two major e-mobility actors, i.e., the Charging Point Operator (CPO) and e-Mobility Service Provider (eMSP) aim to facilitate the deployment and realization of advanced e-mobility services towards improving user's charging experience and satisfaction. This differs significantly from refueling a conventional vehicle, where users are aware of exactly what they will have to pay and how much the fuel costs per liter. The lack of reliable and real-time information on the availability of the charging network is also a concern [3], as charging infrastructures are frequently blocked by parked cars, conventional or electric ones.

Nowadays, most charging stations do not allow booking for charging during a specific time slot, leading to an increase of time spent when looking for a Charging Point (CP) to charge a vehicle. A convenient

Booking Service (BS) is intended to exploit the use of this limited resource in an efficient manner, especially with the increasing use of EVs. To avoid overlapping of charging requests and other operational issues, it is essential to design the BS tool from a practical viewpoint and with a strong user-centered perspective [4].

This paper designs a BS to facilitate EV users to reserve a charging solution (station, mobile or battery swapping) based on their charging preferences and needs as well as the real operational conditions of the preferred charging stations. The service is designed and implemented in the eCharge4Drivers EU project [6] where the BS is designed to improve the EV user's charging experience, avoiding wasting time in front of an occupied charging station. Moreover, it is important to provide to the user the possibility to select, from a list of available charging stations, the most preferable one in terms of technology, energy and mobility needs. The objective is therefore to design and develop an interoperable BS which will for instance enhance the communication of user's reservation requests to the CPO, that is responsible for managing reservations at the charging station level. Short term and long-term reservations are both to be considered and offered to the customers with specific functional requirements and restrictions for serving different mobility needs (i.e., urban mobility, inter-city and long trips).

Three booking services have been identified for reserving the following three different charging technologies leading to different requirements: 1) charging stations, 2) battery swapping and 3) mobile charging. For a correct functioning of a BS, it is fundamental to establish a strategy of data flow between various actors, such as eMSPs and CPOs.

The paper is structured as follows. In the second section, the high-level functionalities for the BS are described. In the third section, the BS use cases are studied and in the fourth section the eCharge4Drivers architecture for the BS design and implementation is reported. Finally, the conclusions and possible future developments in the sector are reported.

2. High level functionalities for the enhanced booking service

In view of a more rapid growth of electric mobility, in which the charging infrastructure will become soon a resource to be shared from a growing number of users, there is the rising need of providing a service capable of helping operators in managing and scheduling the charging sessions avoiding conflicts for customers. The enhanced BS can be a solution that can allow the reservation of the best charging solution for the final users based on their preferences and vehicle travel needs. Moreover, the BS has to enable the operators like CPO to offer a better charging service optimizing the scheduling and calendarization of the charging sessions by avoiding unhappy customers and preserving the grid. Today short-term booking is possible but there is a limited use of long-term booking that enables the potentiality to plan long distance trip charging stops in advance. Moreover, the use of protocols like OCPI and OICP can guarantee interoperability of the solutions so that different eMPs can operate the service on one or multiple CPOs. Moreover, within the booking session, smart charging solutions can be proposed for grid balancing purposes.

The proposed BS is designed to satisfy the following user needs:

- book the charging station both in short (e.g., 15 minutes ahead) or long term (e.g., major than 2 hours ahead) time period (today the long-term booking option is not offered or rarely offered to the users);
- book a charging station that is not reserved or used from another customer when required;
- receive enhanced offline and real time information about the reserved charging station and session via the application;
- synchronize the charging session information with the user digital calendar and receive reminders;
- receive compensations or back up solutions in case the booked charging session is lost due to CP occupied by an unauthorized vehicle;
- use a booking service that can be interoperable with different eMSPs/CPOs, i.e., which work on charging stations also managed by different actors.

2.1 User preferences

The following user preferences are considered in the proposed BS.

Booking time options

- **Short-term booking:** This functionality allows the user to book a specific CP shortly before the starting of the charging session (e.g., at most 15-30 minutes). Once the booking has been validated, the user has this short time to reach the CP. This functionality is useful for short-distance travellers that know the area they are travelling to.
- **Long-term booking:** This functionality allows the user to book a specific CP with more anticipation than just 15-30 min (e.g., up to 24 hours). Whereas short-term booking is especially useful for short trips, long-term booking appears to be advantageous for long trips where having stops planned in advance makes the trip experience significantly more appropriate and satisfying.

Type of charging

- **Slow charging:** When the user plans to stay a long time in a place, the slow charging option is more appropriate. In this case, users will tend to do longer charging sessions that might be planned in advance. Hence, there can be a correlation between slow charging options and long-term booking.
- **Fast charging:** When the user just wants to charge and leave the fast-charging option as soon as they have a significant SoC is more practical. Unlike for slow charging options, users tend to use fast-charging options when they want to spend a short time in the CP location. Therefore, there can be a correlation between fast-charging and short-term booking.
- **Calendar synchronization:** The user should have the option of adding the booking session into their smartphone calendar and get reminders.

2.2 Booking issues

For the BS it is essential that the booked CP is available and free when the driver arrives. In order to reach an efficient use of this tool, it is convenient to consider the occupancy level of the CPs.

- **Occupancy in real-time**: When using the Booking Service, it is essential to display the current status of the CP in a user-friendly manner via the application. This is especially useful for short-term booking users.
- **Occupancy in the future:** When booking a CP on a long-term basis, the Booking Service should also display if the CPs are booked at the time the user wants to make the reservation. Also, if the user is interested in booking a particular CP, the App should allow to tap on this CP and see all the reservations in a time schedule.
- **Timeslot based strategy**: In the long term-booking, there are different ways of defining the time slots to be booked.
    - The time slots are predefined by the CPO or eMSP, the user can select one or more of the timeslots proposed. For example, 30 minutes slots. This makes the operation of the booking easier for the CPO or eMSP.
    - The timeslots are decided by the user, the user can select with total freedom from the starting and finish time of the booking session. This could lead to unexpected booking patterns and to empty slots where no users can use the CP, but at the same time it allows to the user to charge in a more flexible way perfectly adapting to their desired schedule.
- **Waiting list:** The users can choose to book an occupied CP and be directed to a virtual waiting list. If the user that booked first, cancels the reservation, the 1st user in the waiting list will get the session.
- **Gap between reservations:** A gap between two reservation could be established, this could prevent some conflicts between consecutive charging sessions. This gap can either be included in the booked time slot or added as an extra time to avoid conflicts. For example, in the case of Turkey they have implemented a gap of 15 minutes between reservations.
- **Occupancy during booking**: The BS should consider all the details from the current charging session and the following bookings.
    - This way, the user that is charging should receive a warning a few minutes before the charging session is over. This warning could be received by a pop-up notification.
    - If a user starts charging in a CP that is booked a few minutes from then, the user should also receive a warning
- **Booking session overlapping with another non-booked session:** It might happen when user "1" that has booked this CP arrives when the user "2" is still charging the car. One solution to this issue is to notify the user "2" that the used has been booked at a certain time by user "1". However, this might be unfeasible since many CPOs and eMSPs do not want to force users that are charging to leave the CP because it has been booked by another user. Two possible cases can occur depending on the CPO/eMSP agreement on the terms of service use: a) if user "2" does not unplug and remove the EV, the charging session is not stopped but he/she is charged with an increased amount in order to reward user "1"; b) the charge session is stopped for user

"2" that has to unplug and remove the car; c) notify user "1" in advance with a warning message that the booked CP is occupied by another user. In the case c) user "1" can decide to avoid risks, cancelling the booked session (without costs) and booking another available CP in the neighbourhood.

- **Smart charging synergies:** The Smart Charging functionalities can certainly benefit from the booking service functionalities and viceversa. Indeed, the Smart Charging can get information on when the user is approaching or leaving a CP and use this information to provide its service. On the other hand, the user can obtain recommendations on the best time to book its next session from the Smart Charging service, for instance based on the grid availability.
- **Sensors for parking and charging:** In order to have a successful booking experience, it is very important to have a reliable information about the status of the CPs. In order to have a clear picture on the situation, two types of sensors are needed:
    - **Sensor in the charger:** It allows to know whether a charger is busy or not.
    - **Sensor (or camera) in the parking spot:** It allows to know if a CP parking spot is occupied but the charger is not connected (i.e., someone is using it as a regular parking spot).

2.3 Booking commitment

Penalties and rewards strategy are also useful for an efficient booking commitment. In particular, it is adequate to apply penalties to avoid users misusing the service by exceeding their booking time and/or overlapping with other booked session. Moreover, compensations for users that arrive at their booked CP on time and find it is not available because unproperly occupied should also be applied.

- **Penalties:** A user exceeding the time limit of the reservation at a charging spot is potentially leading to a downturn in the user experience for the next users that have booked that same CP, especially for slow charging. This use of the service is unethical and should be penalised accordingly. On the other side, a user arriving to the CP later than the starting time of the booking should be penalised, after a short grace period of time, since there can always be an unexpected delay when travelling to the CP (e.g., when booking a CP, the user has to reach the CP location).

  Also, depending on the context and in case the demand is very high, cancelling the reservation at the last minute could also lead to a decrease in the expected service and consequently should lead to a penalty.

  The different types of penalties can be applied:
    - **Economic:** The users that exceed the reservation time gets charged proportionally to the exceeded time from his/her booking. Likewise, the users that show up late or do not show up get charged a penalty fee.
    - **Banning:** The users that exceed the reservation time, shows up late or does not show up could be banned of the booking service (in case the user does this repeatedly).

- **Losing booking session:** The users that arrive late to the reservation (later than the grace period, if any), could lose the booked charging session.

In case of CP parking spot occupied by a non-EV vehicle a penalty is not applied to the user of such vehicle but a warning message is sent from the booking service both to the EV user and the CPO.

- **Compensations**: The user that arrives to a CP at the time when the booking session starts and finds the CP occupied will waste unexpected time and this may affect his/her schedule. A compensation for this user according to this wasted time should be considered among the following options:
  - **Discount on charging:** give the user a discount for the next charging session.
  - **Book a back-up CP:** provide the user with the possibility to book a back up CP.

It is essential for the system to keep track on the penalties and compensations applied to users in order to impose the defined policies. Also, it should be noted that the different types of penalties and compensations can be combined depending on the context of the issues.

3. Booking service use cases

In this section, high-level use cases are described in order to identify the booking service procedures and the actions to be performed by each involved actor and system.

Three use cases are described according to the three booking services: 1) booking a charging session in a CS; 2) booking a battery swapping system; 3) booking a mobile charging session.

3.1 Enhanced booking service for charging stations

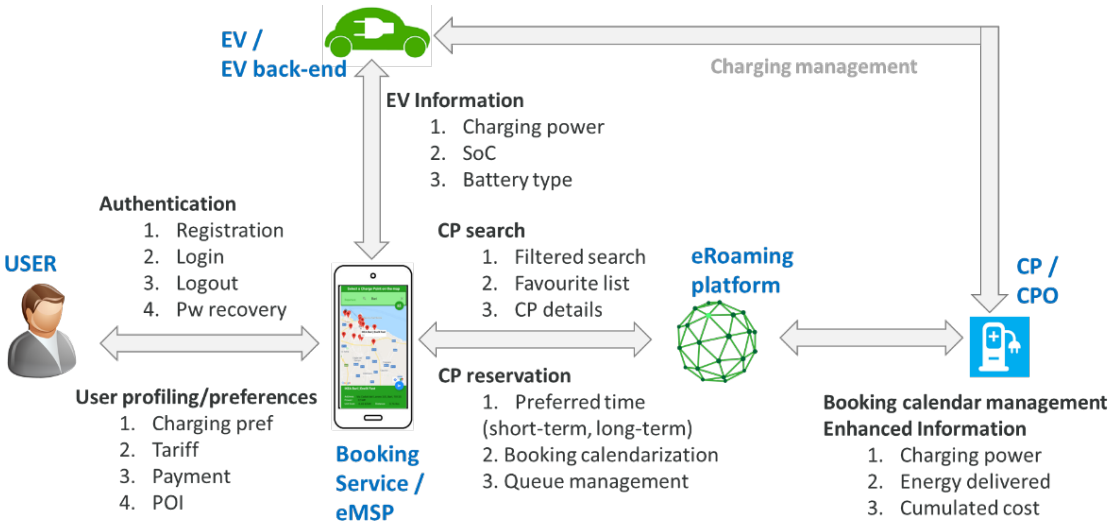

Figure 1. Use cases diagram of the booking service for charging stations

Figure 1 shows the use case diagram of the BS for charging stations. Firstly, the user has to authenticate in the BS application. If the authentication is successful, the application shows the user profile preferences menu in which the user can visualize and edit his/her preferences about charge points on a

map. Based on the charge preferences, on the trip details such as departure and destination points, and on data coming from the EV such as current state of charge and plug type, the booking service searches for the available and reachable charging stations within the interested travel area. Note that if the connection with the EV is not available, the user is asked to insert the necessary data. The list of charging points is returned to the user that can decide which CP to book in a short or long term period based on enhanced information such as, real-time and future occupancy of the CP, charge tariff and cost prediction. The reservation request is done by the booking service to the CPO that can confirm or deny the booking session. In case of booking confirmation, the booked session details are provided to the user and can be synchronized with his/her calendar in order to get useful reminders, especially in case of long-term reservation. In case the reservation is not confirmed by the CPO, the user can go back to the CP list and choose another option. In case the booking session is successfully completed the user will receive all the booking and charge detail records including session times, session and charge cost and delivered energy. In case the booking session can not be joined because of improper occupation by another vehicle, warning messages can be sent in advance to user and compensation policies can be applied.

3.2 Enhanced booking service for Battery Swapping

In the enhanced BS for battery swapping, the user has to authenticate in the booking service application as in the booking service for charging station (see Fig. 2). If the authentication is successful, the application shows the user profile preferences menu in which the user can visualize and edit his/her preferences about batteries to be swapped. Based on the preferences, on the trip details and the light EV info, the booking service searchs for the available battery swapping stations within the interested traveled area and shows them in a map. The user can select the preferred battery type option and ask for the short term reservation through the application. If the reservation is confirmed by the BSS then the user can join the battery swapping service. If the reservation request fails, the user can go back to BSS map and select another available option. Once the battery swapping has been successfully completed, the user can visualize the final details on the session via the application.

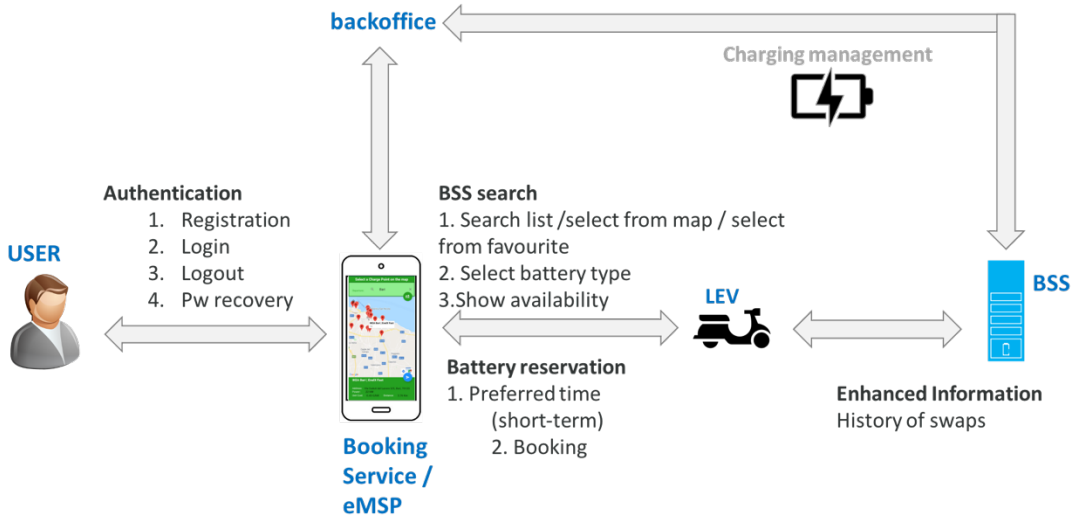

Figure 2. Use cases diagram for the booking service for battery swapping

3.3 Enhanced booking service for Mobile Charging

The use case diagram for the BS for mobile charging is described in Fig. 3.

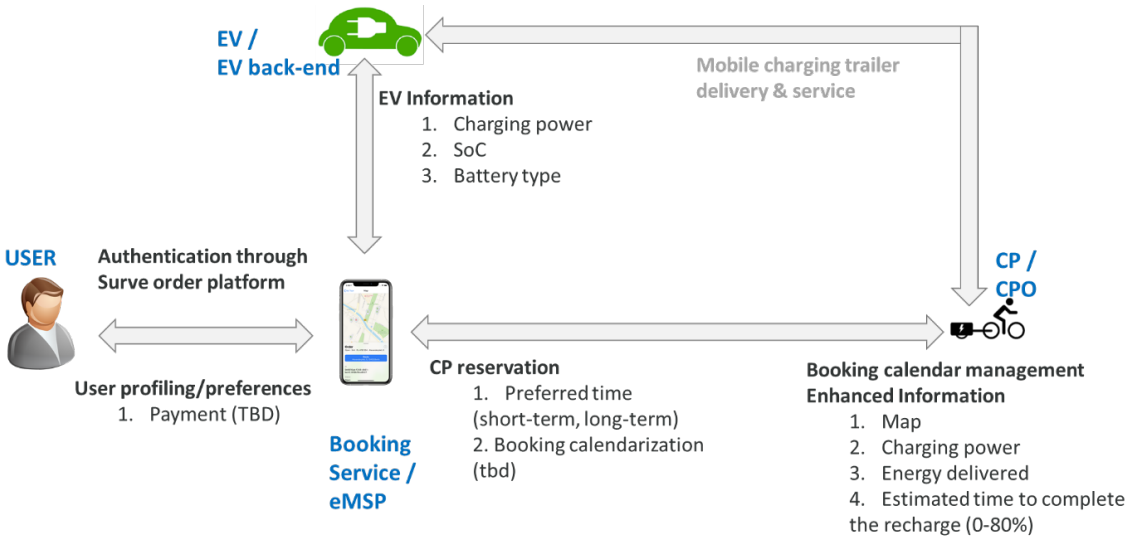

Figure 3. Use cases diagram for the booking service for mobile charging

Due to increasing sales of all-electric vehicles, the need for a well-developed charging infrastructure is also growing. Especially in large cities, where many people live in flats where there is no charging possibility directly at the house, this can lead to problems. Public charging points are sometimes not as numerous as they need to be, which inhibits many people from buying an electric car.

Through the mobile charging solution and the associated service, potential e-car buyers can be relieved of this fear because a charging solution is created on their own doorstep. The mobile charging solution has the

advantage that you don't have to search for a suitable charging station several minutes' walk from your own front door after work or after a big shopping trip. The mobile charging solution is designed as a bicycle trailer, which guarantees emission-free transport to the customer, high flexibility and maneuverability in urban areas. The customer has access to a booking system and can thus customise the charging of the vehicle and adapt it to his/her needs (see Fig. 3). Customers can park anywhere within a predefined business area and call or pre-order the charging trailer via app. Data from vehicle are needed to inform the charging trailer provider about the charging needs. The mobile charging solution is equipped with exchangeable batteries, which guarantees a fast service and a high and dynamic availability. The mobile charging station is brought to the customer and after charging of the vehicle or completion of the charging process by the customer, the charging station is collected again by the service personnel. In the warehouse/hub, the mobile charging trailer can be refilled with fully charged batteries and is ready to be deployed to the next customer.

4. Conceptual architecture and Information flow

In this section we show the conceptual architecture of the BS system that is shown in Fig. 4. In particular, the BS layer is included in the electro-mobility service provider backend. A database module allows to store and access data about the charging sessions and user preferences.

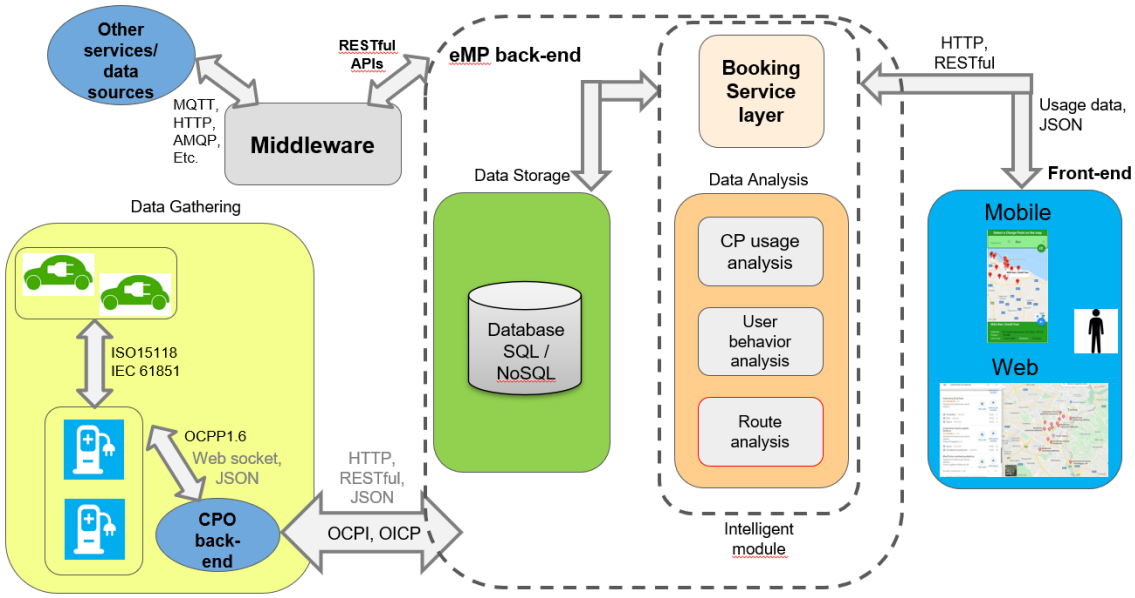

Figure 4. Architecture of the booking service of charging stations

The booking service uses the available data to analyze the CP usage, the user preferences and the travel needs in order to propose feasible charging solutions to be booked, through an intelligent module. The eMP backend can be separated from the CPO backend with which an interoperable communication can be established through Open Charge Point Protocols (OCPP) [7]. In particular, the OCPP is an application protocol for communication between EV CSs and a central management system, also known as a charging station network, similar to cell phones and cell phone networks [7, 8, 9]. Different

protocols can be applied: f. e., the Open Charge Point Interface (OCPI) protocol, that is suitable for being widely adopted for e-roaming, and the Open Inter Charge Protocol (OICP) that is a B2B protocol with the main goal of facilitating e-Roaming services [7, 8].

Thanks to the use of these protocols, multiple eMPs can be connected to one or multiple CPOs to offer the BS. Moreover, the CPO backend, that is in charge of managing the booking calendar, communicate with the charging stations through the OCPP protocol. The BS is provided to the final users through both a web front-end and mobile application. In addition, a middleware module can allow the communication with external services and data sources such as route planners and map service providers.

Final users can join the BS through the web or mobile application. To access the BS, a request is done to the service backend via the application. Once the service access is successful, the BS layer requests the data necessary to satisfy the user needs. A specific database can be accessed to this purpose. In the meanwhile, a communication link is established through the eMP and CPO backend in order to exchange data and information to implement the described booking service functionalities. The CPO is in communication with the charge stations via OCPP protocol to get real time information about charging sessions. At the same time, a communication link can be established with external data sources or services to get additional information for instance about traffic and routes via a middleware by the eMP/service backend. These information are transferred to the booking service layer to manage the booking request at service level. At this level, the BS analyzes the available data about CP, user and route, to propose the best fitted charging solutions to be booked by the final users. The booking session can be monitored and managed in real-time by the users through the application.

5. Conclusions

Electric mobility is the future of the transport sector, and in order for this to be correctly integrated in our cities, it is necessary to introduce adequate charging system. Smart grids and smart charging are only a first step towards a new future full of innovation and possibilities. Using the knowledge generated, the eCharge4Drivers project will determine the optimum mix of charging options to cover the user needs, recommendations for legal and regulatory harmonisation and guidelines for investors and authorities for the sustainability of charging infrastructure and services.

This paper proposes three booking services for reserving three different charging technologies leading to different requirements: 1) charging stations, 2) battery swapping and 3) mobile charging. In order to guaranteeing the correct functioning of the BS, a strategy of data flow between various actors, such as eMSPs and CPOs is proposed. Then, an architecture is proposed for the system that allows the connection between the main actors of involved in the booking operations.

Future research will test the system in different test conditions, simulating the reservations of many users in the same charging station: different capacity, power, initial and final charge, reservation time and flexibility on time, duration, price and final charge.

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