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Electric Vehicles Management for carbon neutrality in Europe

Deliverable D5.2
Standardization gap analysis for new V2X related Business Models

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[1] https://ev4eu.eu/

Executive Summary

The *Standardization gap analysis for new V2X related Business Models* (D5.2) provides an overview of the current communications architectures for Electric Vehicle Charging Systems as well as identifies the main contributions that EV4EU can provide towards the existing standards for this domain.

The document starts by a description of the main standards related with electric mobility and mainly the ones enabling V2X. Afterwards, some barriers are identified considering the use cases already defined in EV4EU and the initial development of the V2X management platform. The barriers already identified will be addressed in the developments of EV4EU and new solutions will be tested in the demonstrators.

The results of this deliverable will be used and updated in Task T10.4 in order to promote the discussion and the project contributions in the standardization bodies that are responsible for the standard development.

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Acronym

BUC	Business Use Case
CCS	Combined Charging System
CPO/CSO	Charging Point Operator/ Charging Station Operator
CSC	Charging Station Controller
CSMS	Charging Station Management System
D5.2	Deliverable 5.2
DMS	Distribution Management System
EMS	Energy Management System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
IEC	International Electrotechnical Commission
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LAL	Local Authorization List
NAT	Network Address Translation
OBC	On-Board Charger
OCA	Open Charge Alliance
OCPP	Open Charge Point Protocol
OTA	Over-The-Air
RES	Renewable Energy Sources
SOAP	Simple Object Access Protocol
SoC	State of Charge
V1G	Vehicle with charging possibility
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VID	Vehicle ID
WP	Work Package
XML	Extensible Markup Language

1 Introduction

1.1 Scope and Objectives

This deliverable aims at the definition of the main entities and communication mechanisms that are used for the EV charging infrastructure identifying the main adopted standards from different entities and organizations within Europe. As a next step it introduces the V2X landscape as well as its associated business models and the contributions of each standard. Then, as a final objective it aims the identification of the main gaps and limitations of the standards towards the V2X direction and provides insight on how EV4EU could contribute to them.

1.2 Structure

The current document is divided into six sections. Section 1 introduces and describes the deliverable. Section 2 defines V2X, present its potential benefits for the grid and also provides an overview on the EV charging infrastructure, considering the relevant actors/stakeholders and standardization bodies. Section 3 provides an insight to the IEC 61851 standard, which describes the EV charging modes. Section 4 introduces OCPP, that is the main protocol used for network communication in EV charging systems. Section 5 complements the previous one by presenting other standardization activities across Europe. Then, Section 6 presents existing V2X business models along with the activities from standardization bodies as well as identifies gaps where EV4EU could contribute to. Finally, Section 7 presents the main conclusions and considerations about the work presented in this deliverable.

1.3 Relationship with other deliverables

Deliverable D5.2 describes the existing standardization activities for the EV charging infrastructure and their ongoing work towards V2X. Moreover, it identifies the gaps and limitations of these standards for V2X. These limitations will be used to devise a contribution plan that will be included in the deliverable D10.7 “Standardisation activities plan” that is due in month 12 of the project. Furthermore, the comparison of existing and V2X communication mechanisms for the EV charging infrastructure will serve as a base for the design of the Open V2X Management Platform that will be part of deliverable D5.3 “High-Level Design of O-V2X-PM” due in month 10 of the project. Finally, the standardization gaps and barriers identified in this deliverable are applicable for the V2X Business Models that are described in D1.4 “Business models centred in the V2X value chain” due in month 10 of the project.

2 Background

2.1 Vehicle to Everything (V2X) introduction

Vehicle-to-Everything (V2X) is a term that contains every solution that deploys the electric vehicle battery storage to power a house, buildings, grids, etc. According to the place where the EVs are connected and the services that can be provided, the V2X ecosystem includes different use-cases based on the utilization of the discharged energy from EV batteries, such as Vehicle-to-grid (V2G), Vehicle-to-Home (V2H), Vehicle-to-Building (V2B) and finally Vehicle-to-Vehicle (V2V). Other similar terms may appear in the literature, such as Vehicle-to-Infrastructures (V2I). V2X implies a bidirectional energy transfer from the batteries to the system (discharge) and from the system to the batteries (charge).

The increasing electricity demands for power supply are constantly being augmented by the EV charging power [1], as it is also described in deliverable D1.4. Hence, V2G can be used as a power supply for the grid during periods of high demand [2], and absorbing excess power during periods of low demand. Specifically, a V2G solution can be used as a buffer in the grid, reducing the power in peak-periods and increasing the power in the valleys. This enables EV owners to reduce their energy bills just by leaving their EVs plugged in when they are not driving them. One additional reason justifying the rationale behind V2G is that the intermittent and variable output of the renewable energy sources (RES), such as wind turbines and photovoltaic power stations, can potentially be balanced [3], [4]. Surplus electricity produced through RES can be stored inside EV batteries [5]. Furthermore, the EVs that are plugged in and are V2G-capable can also serve as an emergency backup power supply [6]. The V2G-capable EVs can thus serve to provide bulk-energy storage, frequency regulation and operating reserves. V2G EVs can greatly aid in the integration of renewable energy sources [7], [8], [9] providing higher levels of flexibility when compared with traditional EV charging control.

From the moment when the EV is connected into the power grid, via V2G, the system operator and mainly the flexibility operators, would have the ability to control the EV battery's charging and discharging process. Each respective EV offers a very small amount of energy to the grid through V2G and, in addition, it is not always plugged into the grid. However, many EVs added together can deliver enough reliable capacity for this energy to be bid into energy markets [10].

To transfer electricity from the EV to the power grid, the direct current (DC) output from the EV battery has to be converted to alternating-current (AC) power of the correct frequency so as to match the AC power and frequency that exists in the power grid. This conversion from DC to AC can be achieved either by means of an inverter built inside the EV or, the most common case, by means of an inverter built inside the Electric Vehicle Supply Equipment (EVSE) [10]. However, there are also a number of technical and economic challenges that need to be addressed for V2G to be widely adopted. These include:

- *Battery degradation*: V2G related determinants such as the total number of charging and discharging cycles of the EV battery, the Depth of Discharge [2] for each cycle as well as temperature effects, can cause degradation, which can shorten the life of the battery and increase costs.
- *Charging infrastructure*: The charging infrastructure for EVs needs to be upgraded to support bidirectional charging, which can be expensive.
- *Standardization*: There is a need for standardization in communication protocols and mechanisms, to ensure interoperability between different EV models and charging stations.

The section that follows presents the communication flows in the EV charging architecture and provides an overview of the existing standardization activities in it.

2.2 Current EV communication architectures

The main entities that are involved in EV communication architectures are: 1) the vehicle, 2) EVSE and 3) the Backend or as termed in literature Charging Station Management System (CSMS) system. The CSMS is responsible for the remote control, monitoring, and maintenance of EVSE as well as the resolution of faults or issues in them. Furthermore, it can also obtain remote diagnostics from the charging stations regarding their health status, real-time availability, and the audit logs.

The EV charging architecture providing the communication flows and the corresponding standards between the EV charging entities is illustrated in Figure 1. The standards impose some control architectures and communication flows between 1) EVs and charging stations, 2) CSMS systems and 3) Different EVs in the V2X ecosystem.

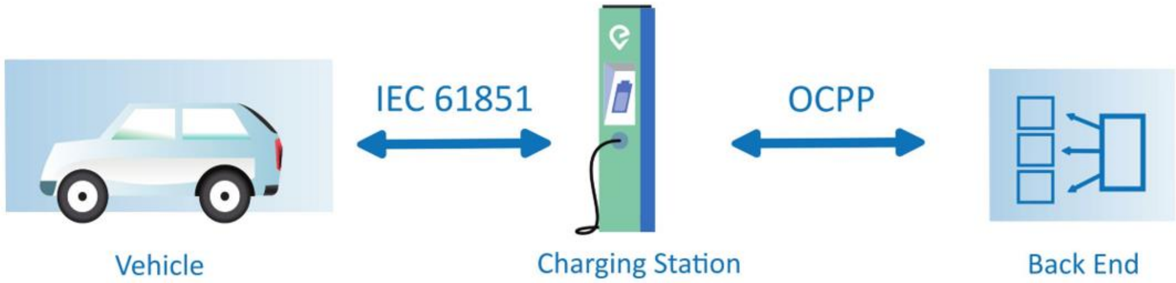

Figure 1 - EV charging architecture entities

The architecture presented in the Figure 1 is a simple example allowing the identification of the main standards used for the communication between the EVs and the EVSE and between the EVSE and the back end of a cloud system. However, this back end can be operated by different stakeholders such as charging point operators, flexibility operators, energy communities, virtual power plants etc. This means that this architecture can be much more complex than the one presented in the figure [13]. Nevertheless, these activities involve actors and entities that are not directly linked with the core V2X use-cases as they are reflected in Section 5 and hence they were considered beyond the scope of this deliverable.

As depicted by Figure 1 each entity invokes a different communication channel using standardized interfaces for data exchange. Specifically, the main standards that are currently used in EV charging infrastructures are the IEC 61851 [11] and OCPP [12]. These standards are further described in Sections 3 and 4 respectively.

3 IEC 61851 standard for the definition of EV charging modes

The EV supply equipment is classified according to IEC 61851-1 in four charging modes [11]. EVSEs with multiple charging outlets may support more than one charging mode. The IEC 61851-1 describes the distinct charging modes and functionalities for the transfer of energy to EVs.

3.1 EV Charging Mode 1

Mode 1 is a method for connecting an EV to a standard socket-outlet (regular domestic-socket outlet) of an AC supply network, by making use of a cable and plug, both of which are not fitted with any supplementary pilot or auxiliary contacts. The rated values for current and voltage in the case of Mode 1 are the following:

- 16 A and 250 V AC, for single-phase power,
- 16 A and 480 V AC, for three-phase power.

The Mode 1 EVSE only provides a protective earthing conductor from the standard plug to the vehicle connector. Its current limitations are subject to the standard socket-outlet ratings. A schematic illustration of Mode 1 Charging is illustrated in Figure 2.

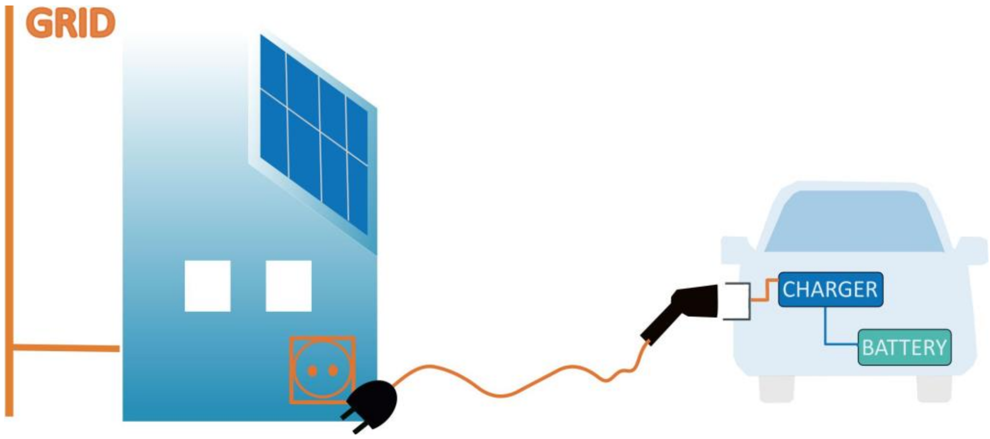

Figure 2 - Charging Mode 1 based on IEC 61851

Mode 1 is the simplest EV charging mode. It does not establish any communication link between the EV and the Charging Station. Instead, Mode 1 foresees the delivery of power from the grid towards the on-board charger (OBC) of the EV. The OBC operates in conjunction with the EV's battery management system with the aim to: *a)* convert the supply voltage to attain the necessary voltage required for the EV battery, *b)* to accomplish constant power charging of the EV, and *c)* to stop the charging process if any fault conditions are sensed in the EV battery or in the supply equipment. The OBC managed by the car control system, also has the ability to enable a scheduling system that lets the driver to plug in but defer the charging process until a specific time (useful when electricity rates are lower at a given period of the day).

It is important to notice that, usually, Mode 1 is prohibited for use in European countries due to the lack of safety measures as the protection against over-current and over-temperature conditions between the standard plug and the EV.

3.2 EV Charging Mode 2

Mode 2 allows to connect the EV to a standard socket-outlet (regular home-socket outlet) of an AC supply network. This is achieved by using an AC EVSE with a cable and plug. The AC EVSE includes a control pilot function [14], which is a communication line used to signal charging level between the vehicle and the EVSE, the EVSE's maximum charging current and any charging errors, and can also be used by the vehicle to initiate charging. Specifically, in Mode 2, the system also checks the continuity of the protective conductor and verifies if the EV is properly connected to the EVSE. Moreover, it energizes and de-energizes the power supply to the EV and takes care of informing the EV of the maximum current that it is allowed to draw. This value might change, without exceeding the maximum allowed current, in order to adapt to power limitations, *e.g.,* for load management. Each connector of an EVSE must have a control pilot that will provide the above-described functions as a mandatory requirement.

Furthermore, the AC EVSE also includes a system dedicated to personal protection against electric shock placed between the standard plug and the EV. Additionally, a protective earthing conductor is used from the standard plug to the vehicle connector. Charging Mode 2 utilizes a special charging cable which is equipped with an in-cable control and protection device (IC-CPD) [15]. The IC-CPD includes all the necessary safety and control functions. The safety functions of Mode 2 charging include detection and monitoring of the protective earth connection, as well as protecting against over-current and over-temperature. Furthermore, the Mode 2 EVSE has the ability to accomplish functional switching by detecting connection to the EV and analyzing its charging power demand. The rated values for current and voltage in the case of Mode 2 are the following:

- 32 A and 250 V AC for single-phase
- 32 A and 480 V AC for three-phase

Its current limitations are also subject to the standard socket-outlet ratings. A schematic illustration of Mode 2 Charging is illustrated in Figure 3.

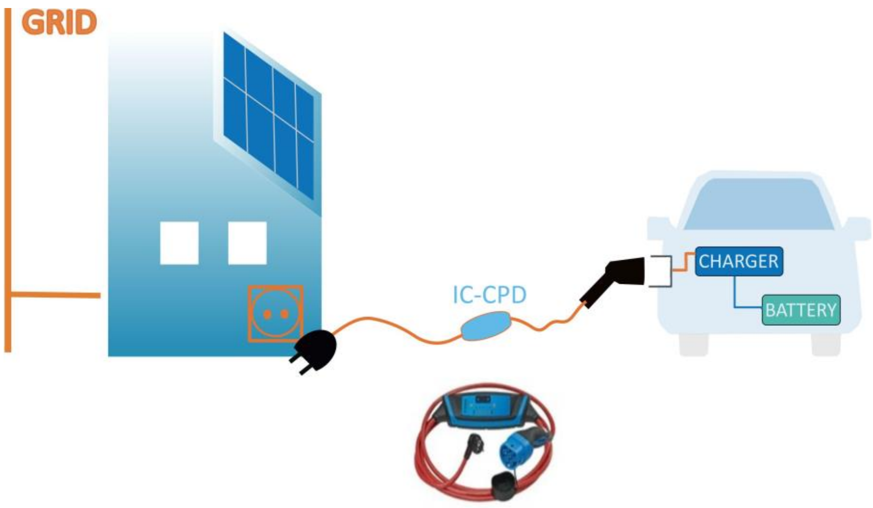

Figure 3 - Charging Mode 2 based on IEC 61851

3.3 EV Charging Mode 3

Mode 3 is a method for connecting an EV to an AC EVSE, which is usually available from an EVSE. The EVSE is permanently connected to an AC supply network, with a control pilot function that extends from the AC EVSE to the EV. EV supply equipment intended for Mode 3 charging provides a protective earthing conductor to the EV socket-outlet and/or to the vehicle connector.

The maximum current that this charging mode can output is 250 A with 250 V for the case of a 1-phase network or with 480 V for a 3-phase network.

A schematic illustration of Mode 3 Charging is illustrated in Figure 4.

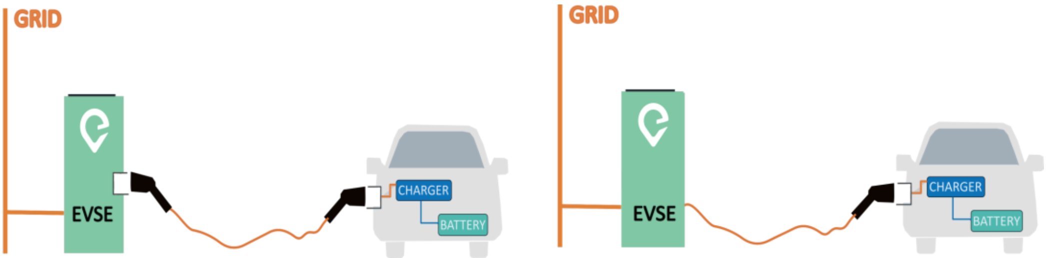

Figure 4 - Charging Mode 3 based on IEC 61851

3.4 EV Charging Mode 4

Mode 4 is a method for connecting an EV to an AC or DC supply network utilizing a DC EV-supply-equipment (DC EVSE), with a control pilot function that extends from the DC EV-supply-equipment to the EV. Mode 4 equipment may be permanently connected to the supply network. EV supply equipment intended for Mode 4 charging provides a protective earthing system protecting the system and the users as well. A schematic illustration of Mode 4 Charging is illustrated in Figure 5.

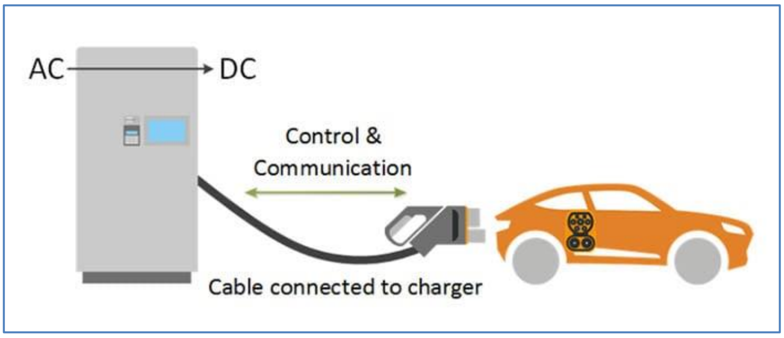

Figure 5 - Charging Mode 4 based on IEC 61851

Mode 4 charging is the sole charging mode which features an Off-Board Charger with a DC output. Meaning that while the first three modes (modes 1-3) deliver AC power to the EV's OBC, in Mode 4, the DC power is being delivered directly to the EV battery. The EV's OBC is bypassed. Comparing with AC charging modes, that are available until 43kW, Mode 4 can achieve higher power levels. Nowadays 350kW EVSE are available in the market.

Note that while the EV's OBC is usually dealing with the AC charging situations, it will also take care of DC charging in case voltage conversion is required (for instance when charging an 800 V EV from a 400 V charger).

4 Open Charge Point Protocol (OCPP) for the definition of EV communication mechanisms

OCPP was initially developed in 2009 by the ElaadNL association, a research institute in Arnhem (the Netherlands). Following its constantly growing adoption, OCPP was included in 2014 within the Open Charge Alliance (OCA) efforts. OCA was funded as a global consortium of public and private electric vehicle infrastructure leaders focused in the promotion of open standards, which also included ElaadNL. Since 2014, OCA took over the leadership for the roadmap of OCPP and the definition of the communication mechanisms between the CSMS and the EVSE.

OCPP is currently widely adopted as it is open standard, which allows to overcome the obstacles and barriers of proprietary protocols e.g., vendor lock-in. Specifically, the standard defines how the EVSE and CSMS exchange messages and commands between them as 1) the initialization of the charging sessions, 2) the termination of the sessions as well as 3) diagnostics as the overall energy consumed during a charging session or the operational status of the charging station. Moreover, it also provides reporting mechanisms and error messages while the station is idle or during a charging session.

A detailed historical overview of OCPP from its initial development till its latest update in 2020 is presented in Figure 6.

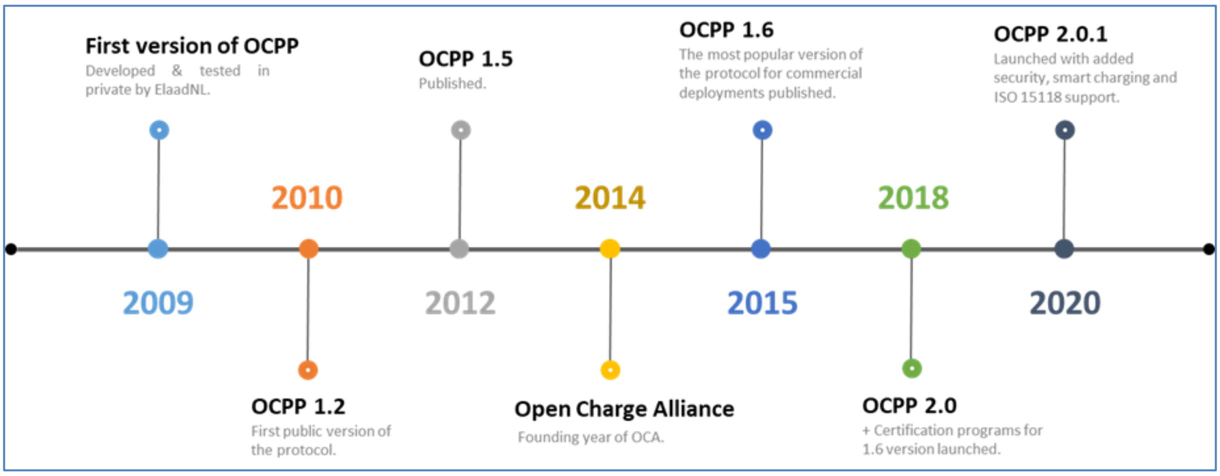

Figure 6 – Historical overview and versions of the OCPP protocol (source [27])

4.1 OCPP versions

OCPP 1.2: The initial version of OCPP defined basic EV charging commands as charging authorization, starting and stopping transactions, obtaining meter values (voltage, current, active and reactive power) during the charging process, charge point configuration and status information. The charging transaction overview is provided in Figure 7. Additionally, remote commands are also defined whilst not in proximity to the charging station, such as starting and stopping the transaction remotely, unlocking the EV cable remotely and OTA firmware updates.

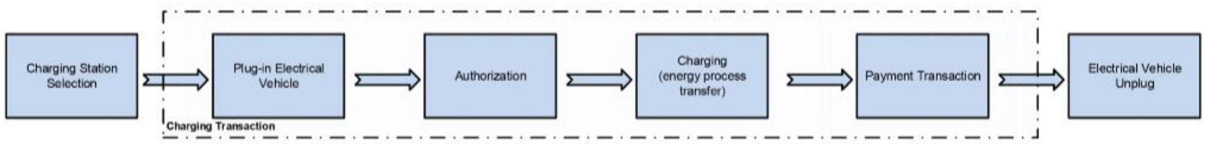

Figure 7 - Charging transaction overview

OCPP 1.5: OCPP 1.5 was based on the SOAP [16], which utilizes XML in order to represent data. This version offers new functions and extensions to the existing ones such as a local authorization list synchronized with the EVSE and a cache to streamline the response times with the EV users. The structure of OCPP 1.5 is described in 25 operations, 10 of which are initiated by the EVSE (authorization, initiation notification, data transfer, diagnosis, firmware status, transaction support), the remaining 15 being initiated by the network's central system (reservations, availability check, configuration, remote transition, connector activation, and firmware update).

OCPP 1.6: The current version of OCPP is widely used in most commercial applications. OCPP 1.6 is an extension of the OCPP 1.5 protocol, having an additional smart charging support. Smart charging allows the EVSEs to be remotely controlled and will thus protect the grid from overloading. Smart charging enables the control of the rate and/or time at which an EV is charged when the EV is plugged in, and it is a one-way flow of electricity from the charging station to the vehicle (uni directional or V1G). The charging rate or the charging time can be adjusted according to the user settings, so as to charge the EV when the electricity is cheapest, cleanest (from RES) or in response to electricity market, network or system signals. Moreover, OCPP 1.6 includes support apart from SOAP for also JSON object transmission over WebSocket formats for reducing the data consumption as well as to enable NAT communication. Moreover, JSON-over-WebSockets simplifies the communications utilizing OCPP client-server architecture [17].

OCPP 1.6 supports a limited set of commands, mainly focused on managing the charging process and providing status information. The most significant amongst them are:

- *StartTransaction*: used to initiate a charging session
- *StopTransaction*: used to end a charging session
- *Heartbeat*: used to check the status of the charging station
- *MeterValues*: used to get the current energy consumption of the charging station
- *Authorize*: used to check if a vehicle is authorized to start a charging session
- *BootNotification*: used to notify the backend system when the charging station boots up
- *StatusNotification*: used to notify the CSMS system of the current status of the charging station
- *FirmwareStatusNotification*: used to obtain the firmware version of the charging station by the CSMS system as well as to perform a remote update in the charging station

OCPP 2.0.1: The latest released version of OCPP with release year 2020. OCPP 2.0.1 contains improvements and extra functionalities for device management, smart charging, V2G support and augmented security measures. In comparison to OCPP 1.6 which supports only limited authorization methods, OCPP 2.0.1 establishes a more advanced set of methods such as for instance remote transactions, PIN-Code, ISO 15118 Plug & Charge, Simple start button, Credit/debit card, Server generated ID, etc. Moreover, till OCPP 1.6 a dedicated Virtual Private Network (VPN) tunnel was needed between EVSE and CSMS to ensure security and encrypted communication channel. However, in OCPP 2.0.1 the data packets are encrypted at the protocol level and thus a secure connection is present [17]. To this end, security profiles for authentication, security logging, secure firmware updates, as well as security event log notifications were added [18].

Furthermore, OCPP 2.0.1 introduced improvements in Transaction Handling to reduce the number of messages communicated between the EVSE and the CSMS for reporting transaction data. This reduces the amount of data used by unifying the structure and method of reporting transactions.

Improvements have been brought also to smart charging in the form of extended functionalities. OCPP 2.0.1 offers the potential for the EV to communicate its requested energy amount in kWh. Such data exchange was not possible in OCPP 1.6 and earlier versions. The EV could only transmit an SoC message informing about the percentage of its battery that was charged at any given time. With OCPP 2.0.1 however, management systems are aware of the amount of energy (in kWh) that an EV needs and adjust the output of the smart charging appropriately.

In addition to the rest of the functionalities, OCPP 2.0.1 has native integration with ISO 15118 to enable functionalities such as Plug and Charge and enhanced data security and cryptography between the EVSE and an EV. The above aids in optimal load balancing and smart charging [18].

4.2 Version comparison

An overview of the differences between the OCPP versions is presented in Figure 8:

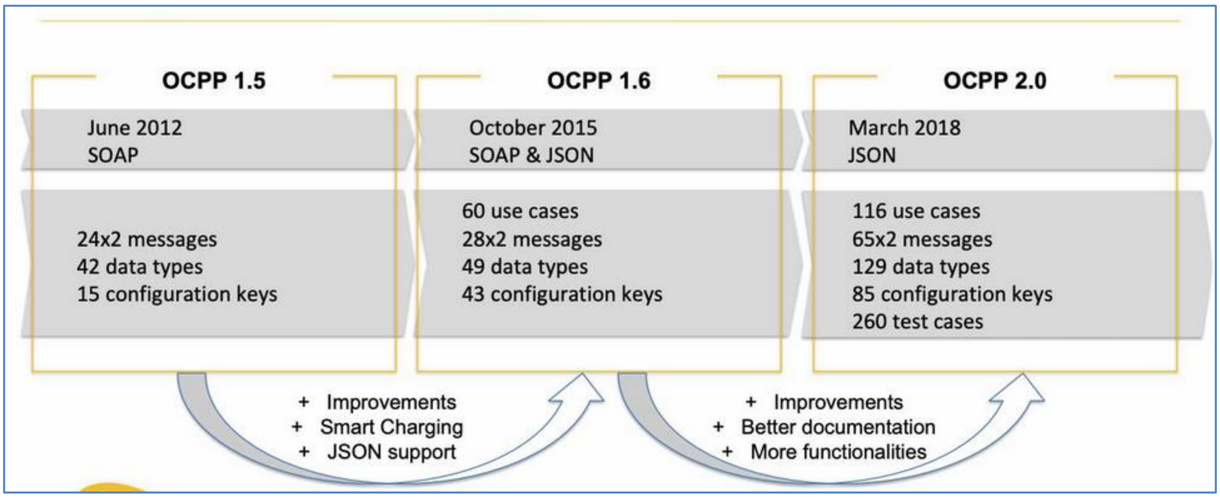

Figure 8 - Comparison of OCPP versions (source:[28])

For enabling the transition towards V2G the following OCPP commands are mainly applicable:

1. *ReserveNow*: This command allows an EV to reserve a specific charging point for a specific period. This is useful in V2G applications where the EV needs to be charged at a specific time in order to provide grid services.
2. *CancelReservation*: This command allows an EV to cancel a previously made reservation.
3. *GetCompositeSchedule*: This command allows the EV to request a schedule of the charging station's availability for a specific period, including information about its current state, planned maintenance, and any reservations that have been made.
4. *SetChargingProfile*: This command allows the EV to set a charging profile for a specific period. This can be useful in V2G applications where the EV needs to charge at a specific rate in order to provide grid services.

4.3 Existing platform implementation

A current CSMS implementation is available within the scope of the EV4EU project based on OCPP 1.6 and is used to conduct experiments aiming the 1) integration and testing of the OCPP standard and 2) research and development of new commands and services to support the OCPP 2.0.1 standard as well as V2G services.

The platform can visualize the number of connected EVSE, the active transactions and sessions (successfully started using StartTransaction). Additionally, it provides real-time status (through dedicated Heartbeat messages and diagnostics of all the EVSE. The platform and its interfaces are under development to include OCPP 2.0 support, however Figure 9 indicates its current state.

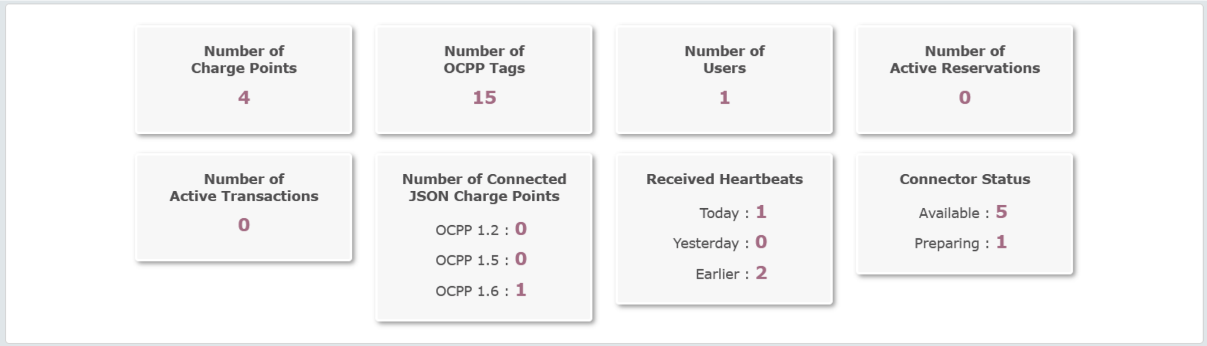

Figure 9 - CSMS platform implementation

The platform provides support for a wide list of EVSE manufacturers. Based on the integration tests that were performed, we have gathered the main results in the Table 1.

Table 1 - OCPP integration test results in the platform

OCPP function	Acceptance Criteria	Result
Boot notification	Receive a (not empty) BootNotification message, containing chargePointModel and chargePointVendor (required by OCPP 1.6), and chargePointSerialNumber, iccid, chargePointVendor, firmwareVersion and chargePointModel	The tested EVSE all generated successfully a boot notification.
Heartbeat (automatic)	Receive OCPP command from CS i.e. heartbeat registered. When CS is not providing heartbeat, send OCPP command to see heartbeat. Provide TCPIP default heartbeat at least every 1 hour from the EVSE (configurable under Set Configuration).	The tested EVSE all generated successfully a heartbeat.
Change availability	After sending ChangeAvailability with type Operative, the status must change to Available.	The implementation of connector names or numbers varied in each

	After sending ChangeAvailability with type Inoperative, the status must change to Unavailable. The availability must be reflected by receiving a StatusNotification message (per socket). Specifically, it is a (not empty) StatusNotification message is received per connector (including connector 0), containing: *i)* If not in error: status with Available, Preparing, Charging, SuspendedEV, SuspendedEVSE, Finishing, Reserved, Unavailable or Faulted *ii)* If in error: error details (errorCode)	EVSE manufacturer but could be configured through a dedicated portal.
Get configuration (list parameters that can be read)	After sending GetConfiguration the Charge Station must respond with a GetConfiguration message, containing the total number of items, followed by a message with the complete list of items.	Stations responded with 15-140 configuration items.
Set configuration	After sending ChangeConfiguration (per item) a message with parameters that can be status Accepted must be received (and not "Not Supported", configured) "Not implemented")	Most of the EVSE had Accepted in their configurations except German manufacturers that do not support certain configuration changes remotely, but only locally due to restriction issues.
Start charge transaction (both local notification and remote trigger)	After sending RemoteStartTransaction the transaction must start, and a StartTransaction message (including transactionId) must be received, followed by several StatusNotification messages (according to OCPP 1.6) Local StartTransaction should start with an Authorize, which – if approved – must be followed by a StartTransaction and several StatusNotification messages (according to OCPP 1.6). If not approved the sequence must stop	All EVSE passed this test as it is mandatory for starting a charging session.
Stop charge transaction (both local notification and remote trigger)	After sending RemoteStopTransaction (by using the transactionId) the transaction must stop, via a StopTransaction message, followed by several StatusNotification messages (according to OCPP 1.6)	All EVSE passed this test as it is mandatory for starting a charging session.

	Local StopTransaction starts with receiving a StopTransaction and several StatusNotification messages (according to OCPP 1.6) When the charging cable is disconnected, a StopTransaction message must be received	
Receive Meter reading	Meter values are received at the start of transaction and stop of transaction Meter values are received, according to meter interval that can be set by user (at least 30 seconds interval when charging) Voltage, current and power reading are received, according to meter interval that can be set by user (at least 30 seconds interval)	Certain manufacturers had the meter values transmission interval set to 0 seconds, however this could still be updated to 30 seconds through a ChangeConfiguration command.
Reset EVSE (both hard and soft reset)	Hard reset (ResetType 0): Charging Station comes online after reset (BootNotification message, StatusNotification message, etc.) Soft reset (ResetType 1): Charging Station comes online after reset (BootNotification message, StatusNotification message, etc.)	An adequate number of EVSE do not implement Soft reset only Hard reset, which increases the downtime of the EVSE when reset is used to resolve issues on it.

5 Further standardization activities

Apart from the main standards for the EV charging architecture, there are further standardization bodies producing initiatives that are divided in two categories: 1) the initiatives that are complementary and hence integrated with the main standards and 2) the initiatives which are standalone, and their integration is in progress. The first category includes ISO 15118 and the CCS, whereas the second includes the IEC Technical Committee 69 (TC69) initiative named as Joint Working Group 11 (JWG11). The latter has defined the standard IEC 63110 [20], which is focusing on the architecture and management of Electric Vehicles charging and discharging infrastructures. IEC 63110 has initiated discussions with OCPP, to establish integration points, however no concrete outcomes from this discussion have been reported yet.

5.1 ISO 15118

ISO 15118 defines the communication interface between the EV and the EVSE for V2G scenarios. When compared to IEC 63110 it provides additional data security using cryptographic mechanisms. Moreover, it enables the so called "Plug & Charge" functionality. Plug and Charge enables EV drivers to charge just by plugging their EVs into the EVSE, without any authorization such as mobile app, RFID card or payment methods (*i.e.*, credit card). This is feasible by identifying first the VID (*i.e.*, MAC address of the vehicle) and then the initial authorization through an RFID card or smartphone app, which will also link to the payment method chosen by the user. Using this information, the next time the user plugs the EV in the EVSE, the charging will start automatically and will also stop by unlocking the EV and no further action for authorization is required. The "Plug & Charge" functionality is illustrated in Figure 10.

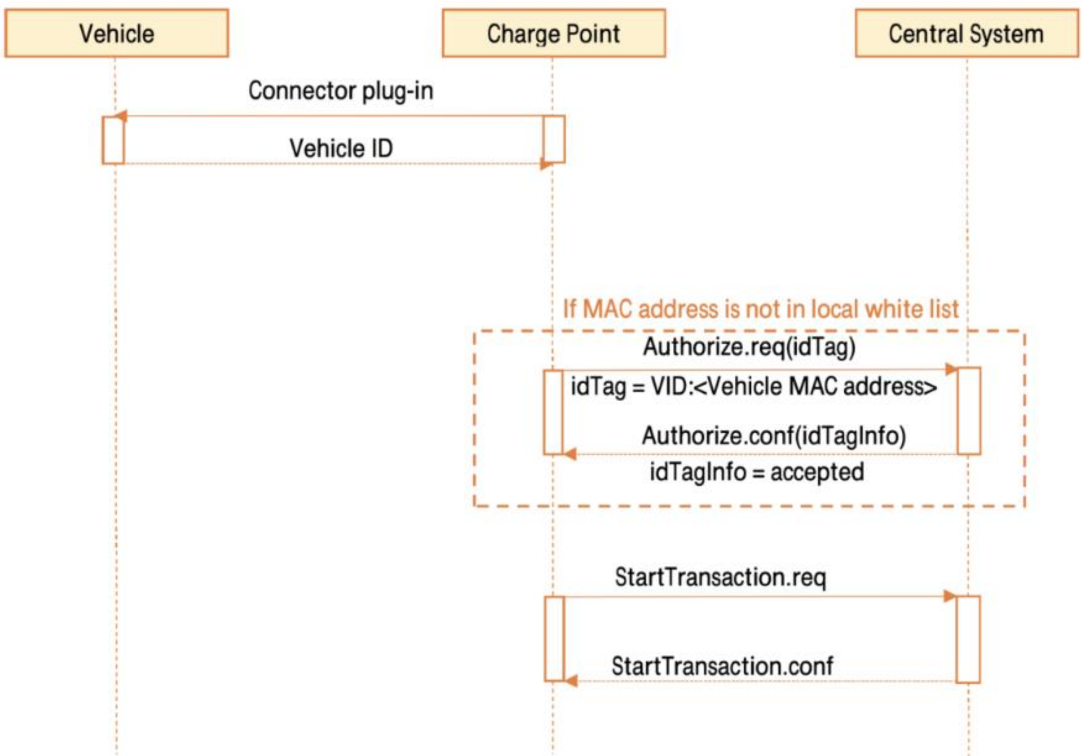

Figure 10 - "Plug & Charge" functionality

Furthermore, the EV uses the ISO 15118 to transmit the State of Charge (SoC) to the EVSE and then to the CSMS. This allows the EV to automatically identify itself to the EVSE and obtain access authorization for the energy it requires for charging its battery. Such scenario is illustrated in Figure 11.

Figure 11 – ISO 15118 for SoC transmission

ISO 15118 also aids in Smart Charging by allowing the EVSE to get input from the EV. Through its new version (namely, ISO 15118-20), it incorporated a dynamic mode for smart charging and V2G functionalities, in AC and DC charging. The overall goal is to foster an early convergence of the various proof-of-concept V2G tests [21].

Finally, as ISO 15118 and IEC 63110 are both standards that cover the communication between electric vehicles and the grid, including V2G functionality, they have a set of commands to manage the V2G process. They have different commands than OCPP, some of them include:

1. *PowerDelivery*: used to negotiate the power delivery between the EV and the grid
2. *ChargeParameterDiscovery*: used to discover the charging parameters of the EV
3. *PreCharge*: used to request a precharge before starting the V2G session
4. *ChargingProfile*: used to set the charging profile for the V2G session
5. *ServiceDetail discovery*: used to discover the available services in the V2G station

5.2 Combined Charging System (CCS)

The CCS standard defines the interface for AC and DC charging of EVs. For AC charging, it supports three-phase power supply with the highest charging power capability of 22 kW for home charging and 43 kW for public charging (subject to the car charging power capability and grid availability). The CCS comprises the connector and inlet combination along with all the control functions. Moreover, it also covers the management of the communications between the EV and the electrical infrastructure.

Figure 12 illustrates the various versions of the charging interface of CCS along with the different connector types according to the Type 1 and Type 2 interfaces that are defined based on the IEC 62196 standard [31].

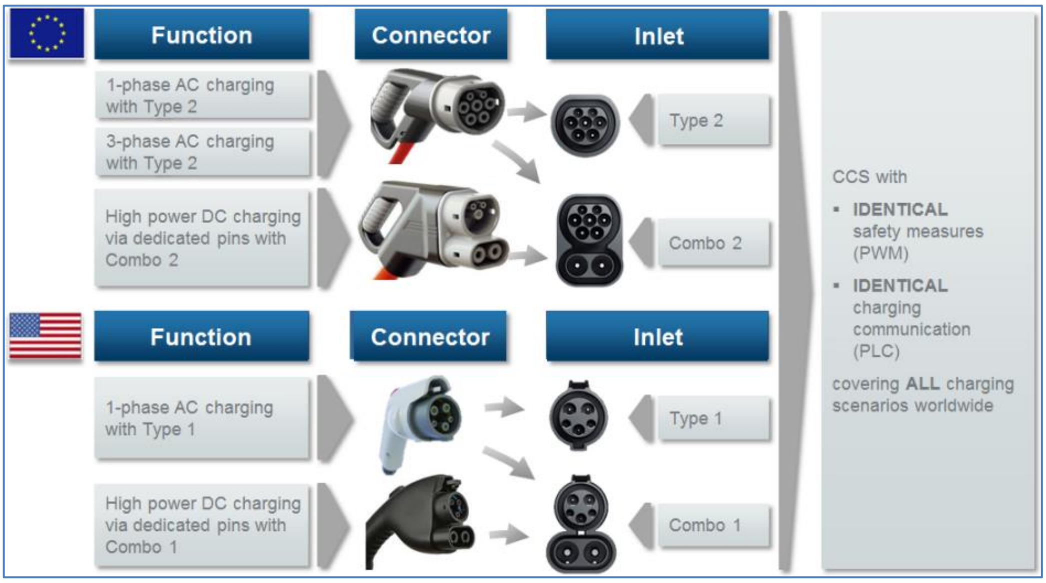

Figure 12 – CCS Charging Interface (source: [29])

Based on this figure the main CCS standard characteristics are: 1) a combined charging inlet per EV (depending on the charging situation only the AC or the DC piece can be used) and 2) a single interface with same charge control logic for all charging situations.

Moreover, Figure 13 illustrates the main standards that are defined for the CCS interface.

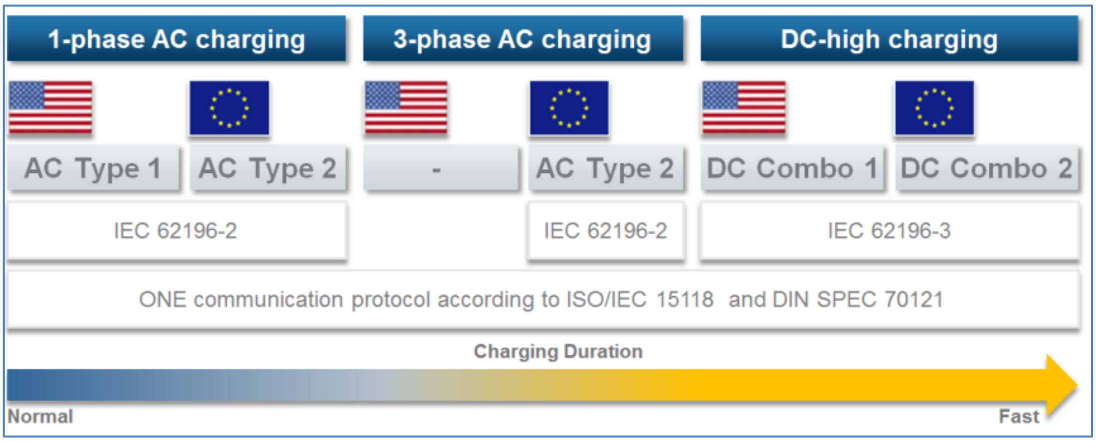

Figure 13 – CCS standards for AC and DC charging (source: [30])

The CCS is hence an integrated solution for both AC and DC charging. An EV is "CCS-capable" if it supports either *a)* AC charging with Type 1 (US) or Type 2 (Europe) Connector according to IEC 62196-2 [14] and *b)* DC charging with Combo 1 (US) or Combo 2 (Europe) Connector in IEC 62196-3 [22].

CCS is maintained by the Charging Interface Initiative e.V. (CharIn) association, whose members include cross-industry stakeholders, for example automakers, charging station manufacturers, component suppliers, energy providers, grid operators, etc. CharIn strives to promote interoperable charging, in which EVs, EVSEs, and software systems work seamlessly together with the goal to achieve a reliable and smooth user experience [23].

CharIn defines V2G use-cases where the DC EVSEs with CCS plug can be used without the need of an inverter inside the EV, which means that the DC power from EV battery becomes AC power for grid injection. An existing collaboration is present between EcoG [24] and several charging stations manufacturers on V2G EVSEs for residential usage of rated power of 11 kW and 22 kW.

5.3 IEC 63110

A standardization initiative led by IEC Technical Committee for EV charging architecture is entitled "Management of Electric Vehicles charging and discharging infrastructures" or IEC 63110 using its unique identifier. Similarly to OCPP, IEC 63110 is one of the protocols which can be used in order to specify the communication link between the communication controller inside the charging station and the software modules in the CPO's backend system. In other words, it defines the communication link for the exchange of information between the charging station and the IT system of the managing CPO. IEC 63110 was conceived in order to tackle the OCPP's lack of compatibility with the smart grid communication protocols. The objective was to essentially create a standard which would be able to enable the inclusion of charging stations management into the smart grid [21]. Figure 14 below depicts the general IEC 63110 communication architecture based on [25]. The IEC 63110 standardization effort for defining the communication link between the Charging Stations and the CPOs was introduced initially in January of 2016 by utility companies as EDF in France, ENEL in Italy and Innogy in Germany. It consists of the three main parts: 1) IEC 63110-1, which contains the basic definitions, use cases and architectures, 2) IEC 63110-2, focused on technical protocol specifications and requirements and 3) IEC 63110-3 having the requirements for conformance tests.

In comparison to OCPP, IEC 63110 introduces a different architecture where the apart from the centralized CSMS there is also a local CSMS used to optimize the energy in the building and interface with the CSC. The local CSMS communicates with a Customer Energy Management (CEM) system for allocating power to the electric mobility usage. Hence, it serves as an edge entity which may receive information and configuration for the central CSMS (possibly deployed as a Cloud service). To this end, the central CSMS is not a "single-point-of-failure" when an operational or cyber-attack incident happens and if the communication link between the local and the central CSMS is broken the local CSMS can still take decisions using all the information it has. This architecture is illustrated in Figure 14.

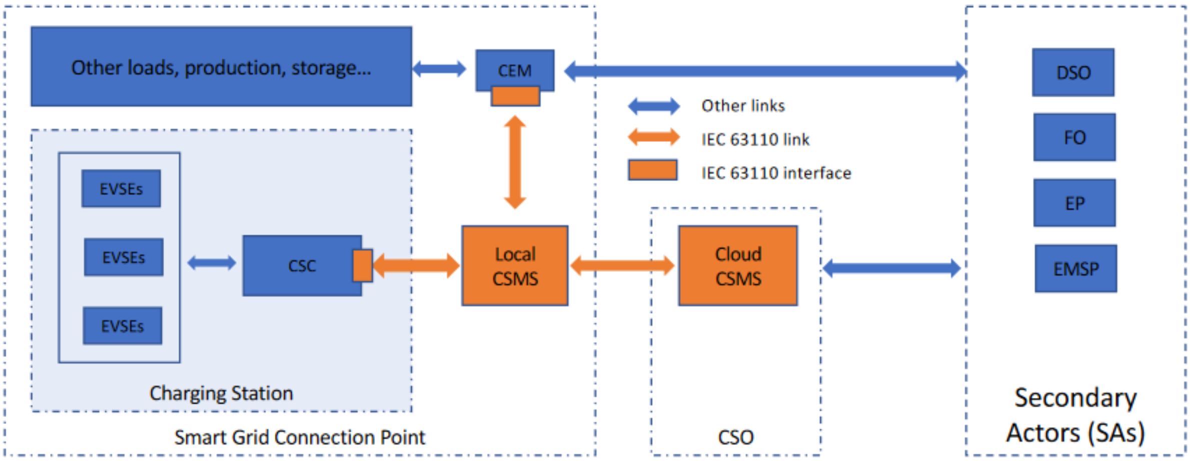

Figure 14 – General IEC 63110 communication architecture (depicted in [25])

In summary, OCPP tackles on the management of EV charging process, while IEC 63110 is deepened on V2G functionalities, they include commands to manage the power delivery, charge profile and service discovery for V2G. However, it remains as a work-in-progress and communication mechanisms are not fully defined yet. Hence, its adoption is not wide as with OCPP and concrete integration tests are not performed yet.

6 V2X business models from existing standards and identified gaps

To integrate the V2X business models into the market, regulatory barriers need to be lifted. In today's world of grid operators, energy suppliers and regulators, impose a highly regulated market [6]. As an example, mobile energy storage systems are currently taxed twice as much as stationary energy storage systems. That is, both when charging and discharging. Additionally, a lack of incentives is also present for persuading the EV drivers to charge their EVs at times that are beneficial to the system. Greenhouse gas emissions related incentives are also not present for the customer at the moment. Appropriate legislation moves and changes are necessary to shape the appropriate framework for this new V2G flexibility.

It is vital that the costs, benefits, and requirements related to V2X are balanced equally and fairly amongst the three main stakeholders. Meaning, EV owners, EV manufacturers, and grid operators [17]. EVs should be able to permit two-way electricity flows between the EV and the power grid. The EV manufacturer should also consider the possibility of V2X in the warranties provided for the car and more specifically, the batteries. Currently, it is not completely clear what impact V2X has on the batteries health status. The EV owner has to be sufficiently compensated for letting the power grid operator use the EV to deliver grid services and also has to be reassured that the EV will be available for personal use when needed. The flexibility operator or aggregators should also be able to derive enough value from the availability of EVs to compensate for the added cost of controlling and monitoring the various vehicle-grid interactions, paying EV owners, and generally managing the whole system [10].

Another significant barrier that exists and that affects the customers perception towards V2X is the battery degradation that occurs to their EV's battery. This concern of the EV drivers can be mitigated if special agreements are made with car manufacturers, charging station manufacturers, as well as CPOs [32]. Such arrangements can make sure that the car manufacturer would extend the warranty of the EV battery for the warranty to additionally include V2X, if there exists a mutual agreement between the CPO and the charging station manufacturer relative to how the EV charging profiles are adjusted.

By focusing specifically in V2X additional use-cases relate to:

a) <u>Bulk-energy storage</u>: where the EV batteries will be absorbing the excess electricity when the generation exceeds demand and will be delivering energy if the generation is lower than the demand. However, using V2G-capable EVs as bulk energy storage could prove to be economically challenging. This is because the EV owner is solely being compensated for the electricity that the EV delivers to the grid at the market price difference between the periods of high and low demand. To remediate this, a feed-in tariff would be needed to make V2G bulk energy storage economically appealing for the EV owners. This use case will be tested in the EV4EU Portuguese demonstrator [33].

b) <u>Peak shaving</u>: Management of EVs charging or even controlling V2X can be used to reduce the high demand charges for industrial or commercial electricity users. The demand charge is established based on the highest single period of demand for the duration of each month. V2X can yield a reduction of the peak demand during that single period and could therefore yield significant savings for the industrial or commercial facility. A large power capacity V2G EVSE can lead, if allowed by the EVs, to high level of peak shaving. This use case will be tested in the EV4EU Slovenian demonstrator [33].

c) <u>Regulation services:</u> V2X-capable EVs can aid in maintaining the balance between power generation and power demand on the grid. Many V2X-capable EVs serve as a regulation service provider that could inject power into the grid when the demand exceeds generation and absorb power from the grid when generation exceeds demand. These short-periods "regulation-up" (power injection to the grid) and "regulation-down" (power absorption from the grid) services can aid in balancing the grid almost instantaneously. The EV owners are compensated for this service based on the number of EVs needed to provide the service successfully, the amount of time per day that each EV is connected and actually committed to provide the necessary grid services, and the power rating (kW) of the EVSE and of the corresponding power line. This use case will be tested in the EV4EU Danish demonstrator [33].

d) Operating Reserves: V2X-capable EVs can aid in providing electricity in the case a baseload generator fails or in the case the electricity generation from variable renewable energy sources such as solar and wind is dipping in output due to, for example, clouds passing over the PV panels. In this way, V2X aids both in guaranteeing a predictable and steady output from renewable energy sources, and in providing a revenue stream for the EV driver for delivering the service (subject to the time the EV is connected to the grid, the EV's battery size and the amount of energy available from the EV to be supplied to the grid). This use case will be tested in the EV4EU Danish demonstrator [33].

e) Behind-the-meter: Intelligent management of electric vehicles charge and discharge introduces higher levels of flexibility in the management of installations such as houses, buildings, parking lots and energy communities. Normally this is called in the literature as behind-the-meter management [34]. In that case the use of V2X will be different according to the strategies adopted by the V2X managers that operate the behind-the-meter installations. Some of the strategies can be minimize the billing costs, maximize the self-sufficiency, maximize the profits, etc. Several use cases will be tested in the different demonstrators in the EV4EU project as reported in the deliverable D1.4 [33].

f) Grid services: Another use cases where the V2X can be important are in the contribution to mitigate grid issues such as voltage and congestion constraints. These services should be activated by the DSOs and, in collaboration with the flexibility operators, can be provided by EVs. This use case will be tested in the Portuguese and Greek EV4EU demonstrators [33].

6.1 V2X Use Cases in existing standards

OCA has formed a dedicated Technical Working Group (TWG) for preparing the V2X standards and associated use cases. In this group all the questions, comments, remarks and the new developments for OCPP are discussed. As an integral part of the TWG there is also the V2X Task Group [18]. In the V2X Task Group the participants focus on the technical development of V2X functionality for OCPP. Monthly calls are conducted to aid in the standardization efforts of V2X and its integration into OCPP. In the V2X Task Group, V2X use cases are gathered, discussed, and processed during the meetings, in which EV4EU actively participates. The V2X Task Group defines the following Use Cases:

1) Central Setpoint

   This use-case considers the situation where the CSMS sends a setpoint to the charging station. At that setpoint (value) the EV should either charge or discharge its battery. It can also provide a bandwidth for the setpoint (Figure 15). The central setpoint will be used in the EV4EU project in the Greek and Slovenian demonstrator.

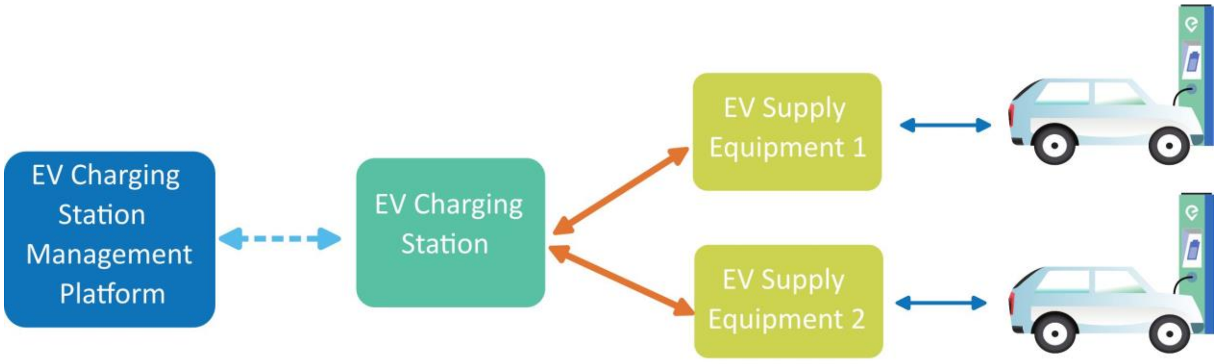

Figure 15 – V2G Central Setpoint Use Case

2) External Setpoint

This use-case includes two scenarios (Figure 16):

a. The first case here is that an EMS provides the setpoint. The CSMS instructs the charging station to receive a setpoint from the EMS. The CSMS has control over the EMS's profile.

b. The EMS is given complete permission to set a charging profile. The EMS is in full control of the profile.

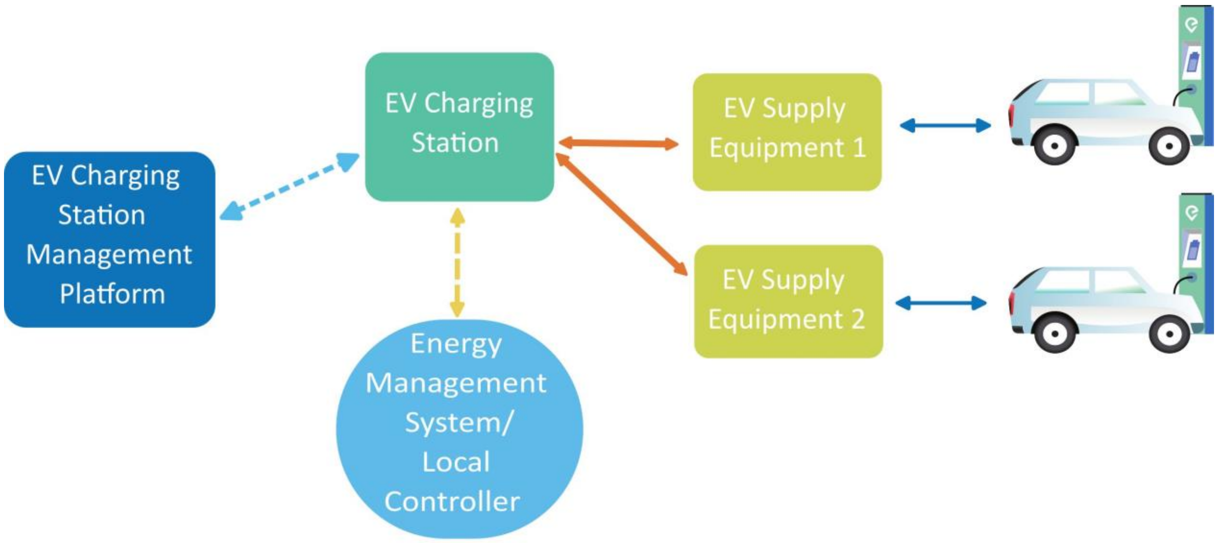

Figure 16 – V2G External Setpoint Use Case

The external setpoint will be used in the EV4EU project in the Portuguese and Danish demonstrator. In that cases an energy management system will be in place to manage the EVSE to provide the required services. Afterwards, some external orders (services activation) can be activated by the system operators or by the flexibility operators.

3) Frequency Control

This use-case deals with the situation in which the goal is to maintain a stable grid frequency. The EVs are delivering energy to the grid when the frequency drops below a certain threshold and they are absorbing the surplus energy from the grid when the frequency exceeds a certain threshold (Figure 17). This use-case is related to BUC 7: Frequency Control Services Procurement and Activation described in deliverable D1.4 [33]. Here there are also two scenarios:

a. In the case of Local Frequency Control, the CSMS submits a charging profile with a power-frequency table (it contains power-frequency values). The charging station adjusts its charging/discharging power based on that power-frequency table that it received. The frequency readings can take place locally if the EVSE possesses a frequency meter.

b. If the charging station does not possess its own frequency meter, then the CSMS can provide the frequency related information to the charging station. This is called Central Frequency Control. The CSMS here changes the power based on the net frequency. The CSMS has to update the charging profile regularly (the existing charging profile can be modified instead of submitting a new charging profile every time).

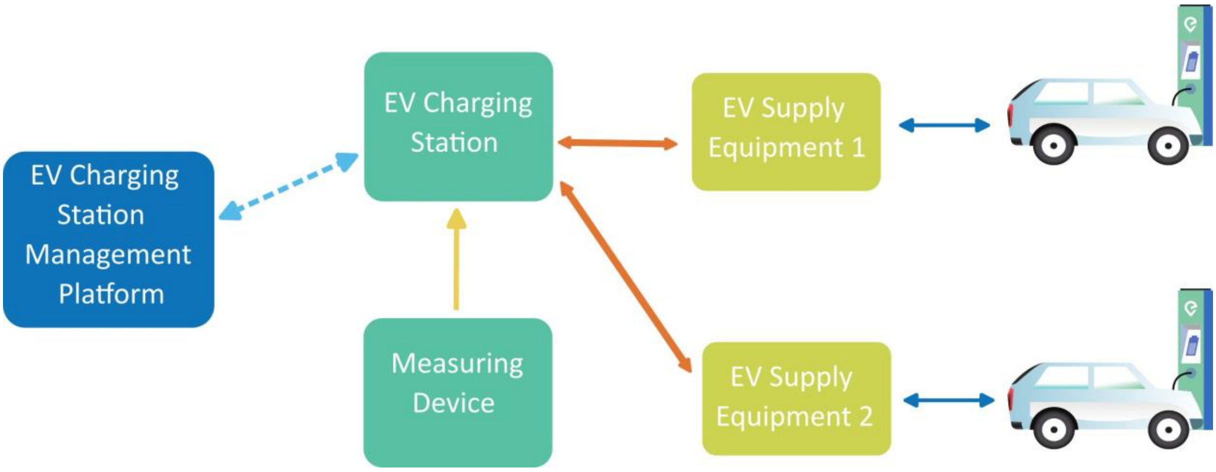

Figure 17 – V2G Frequency Control Use Case

Frequency regulation services will be tested mainly in the Danish demonstrator of EV4EU project. However, in that case, the measuring device will be included in the charging station, or more specifically, in the controller of charging station. In Portugal, this service will be also tested in the case of the company demonstration.

4) Local load balancing

Here, the EV is used to limit the amount of power that is drawn from a grid connection. In the case of local load balancing the CSMS is asked to set an upper and a lower threshold. Then the charging station will make sure that the setpoint is set in such a way so that it compensates the measured load and stays within the thresholds. The result is a behavior that stays within the thresholds. Moreover, local load balancing having the thresholds equal to zero can lead to a V2H scenario (Figure 18).

The charging station can be connected to the building's smart meter (in a V2H situation), and thus know what the energy consumption of the building is. Then an upper and lower threshold can be defined by the building/house owner. The charging station will make sure that it stays within these thresholds. If the building's power consumption increases, then the EV will start discharging so that the net power usage is compensated for and vice versa. This use-case is related to the BUC 4: DR Services for RES and EV coordination and BUC 5: Dynamic V2X Capacity Contracts Procurement and Activation described in deliverable D1.4 [33].

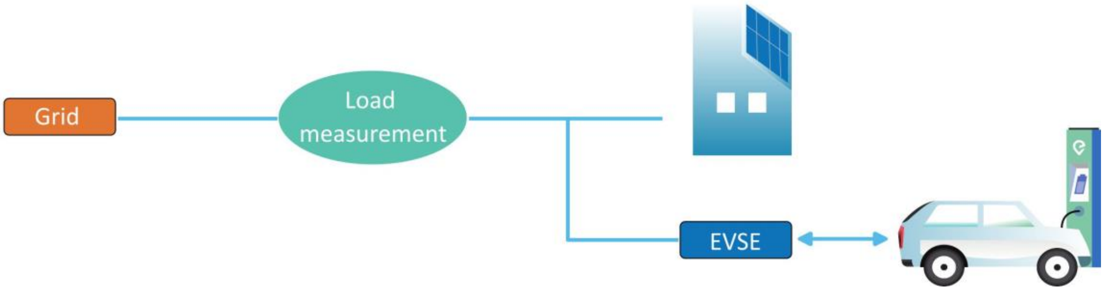

Figure 18 – V2H Use Case

5) Local Voltage Control

   The charging station measures its local voltage and, depending on a voltage vs power-factor table that the CSMS has provided (in the form of a charging profile), it changes the amount of reactive power. This service will be tested in the Portuguese demonstrator of EV4EU project.

6) Priority charging

   This use-case concerns the situation in which the EV user has allowed its EV to be used for frequency control, but he/she decides to halt the service he/she is providing and leave in a hurry. This introduces the concept of priority charging. The way this is implemented is that there exists a priority charging profile which will offer to the EV driver the maximum power allowed. This service will be tested in the Greek demonstrator of EV4EU project.

A preliminary specification exists within the V2X Taskgroup, containing a description of the use-cases, messages, data types, JSON schemas. Additionally, pilot implementations are also on-going with partners implementing these schemas and sending back feedback. Furthermore, new use-cases are being investigated for injecting reactive power, such as V2H and V2B. Existing pilot projects related to the above OCA V2X Use Cases include:

1) Dreev: Local frequency control with 150+ V2G DC charging stations utilizing ChaDeMo.
2) BMW/Kostal: Local load balancing (V2H) with central setpoint (intraday trading, peak shaving)

6.2 Current limitations gaps in standardization activities

Based on the previous analysis, the following limitations and gaps were identified:

1) Security challenges evolve from the amount of data sent and received and the number of system devices. Data integrity assurance in each device (EVSE, CSMS, EV) is crucial and needs to be addressed. Cybersecurity monitoring is another aspect that should be monitored. All the IT maintenance costs may sum up to a significant amount. Certain grid services such as spinning reserves can be performed making use of low-cost wireless service but adding others (adding load balancing) can require a more reliable (and significantly more costly) copper-wire service [2]. All these costs as well as a profit margin should be borne by an entity such as the flexibility aggregator. Specifically, 40% to 50% of the revenue obtained for the V2G services might go to the system aggregator to compensate for its operating expenses and profit [10].
2) The participation on grid services can be limited by the existing electric installations. In some cases, the charging station can be connected in points that can introduce some limits in the power that can be discharges to the grid due to technical limits. The same can happen in the charging limits imposed in the charging stations.

3) For some services, the system operators or markets can impose a minimum power to participate in the services. This can limit the participation of slow charging stations in these services.
4) Another aspect that can limit the participation of EVs in some services is the need to provide services during a pre-defined period. To guarantee the services, the EVs should have enough capacity on their batteries. This can limit the participation of small EVs in the mentioned services.
5) Currently there is no standardized Minimum Plugged-In Time for the EVs that are participating in V2X endeavors. It depends on the contract with EV drivers. This can result in the EV drivers participating into contracts which are too binding for them because they require them to have their EV plugged in for many hours. This can result in the EV driver breaching the contract, which in turn leads to unreliable grid services and reduced revenue for the EV driver.
6) The inverter performing the conversion from the DC power of the EV battery to the AC power of the correct frequency for grid injection is not standardized yet. It can either be placed inside the EV or inside the EVSE. Meaning that the cost can either be burdening the EV manufacturer or the Charging Station Operator. If the cost is on the EV manufacturer's side, then eventually it is burdening the EV driver. If the cost is on the CSO side, then it can possibly not be burdening the EV driver.
7) There currently is no single standardized communication protocol for the V2G communications between EVSE and CSMS (OCPP 2.0.1 is on the move to enter the V2G market).
8) Currently there is no standard that dictates that EVs need to be manufactured having V2G in mind. Currently there exists a limited number of EVs in the market capable of performing V2G functions. This leads to a restriction of choices for the EV users.
9) Remuneration strategies related to the participation of EVs in services is not defined. Afterwards, V2X management should have a different remuneration when compared with the management of the charging process.

7 Conclusions

This deliverable provides a definition of the communication mechanisms as well as the primary entities which are involved in the EV charging infrastructure landscape. Moreover, it describes the basic standards from different entities (*i.e.*, institutions/organizations) that are currently being followed within Europe for the EV charging infrastructure. Furthermore, it introduces the V2X landscape and its associated business models. Then, it provides the contribution of each standard in the V2X business models. Finally, it discusses the main gaps and limitations that exist in the current standards, which inhibit the V2X integration and provides insights on how EV4EU could contribute towards these limitations.

In summary, from the analysis performed in the present document, it is possible to conclude that standards should evolve to include V2X. However, the services and business models of the different stakeholders should be adapted to include the possibility of V2X. Another important gap that has been identified is the adequacy of the EVs concerning V2X. In some cases, the EVs impose some limitations in this process.

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