

EV RELATED PROTOCOL STUDY

Original Study Report
Version 1.1

Elaadnl



ElaadNL

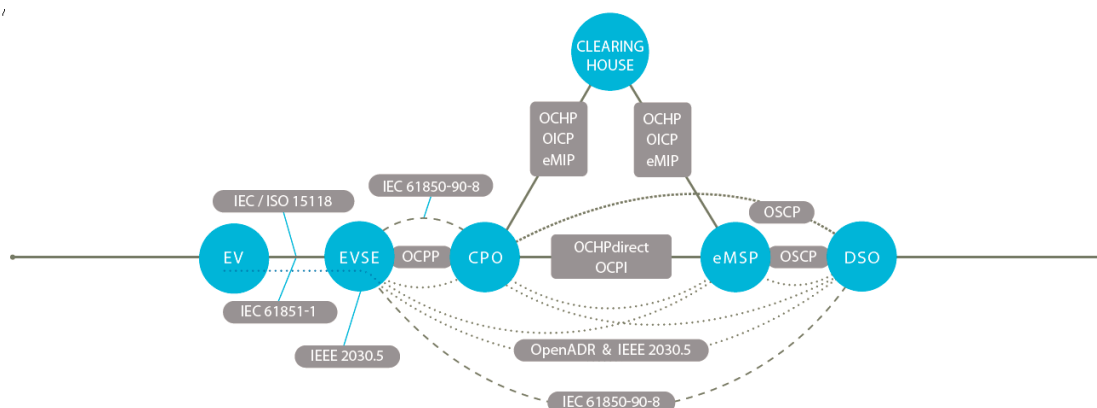
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Executive summary

Based on its practical experience, ElaadNL has come across many different protocols within the Electrical Vehicle (EV) domain. The interaction supported by these protocols consists of exchanging information ranging from authorization identifications (ID) to charge point locations, but also of sending commands for charging control. In this study, a selection of protocols encountered by ElaadNL is discussed. These protocols and the relation to the different roles in the EV market are visualized in the figure below:



In the figure above many protocols are shown, even multiple occurrences of the same protocol between different roles are visible. At different locations, the use of different combinations of protocols were found, including a number of different protocols for similar functionality. From ElaadNL's role as a knowledge and innovation center in the field of EV charging, this study aims to give more insight in a set of protocols that is currently in use in Europe and to clarify their relationship to the electricity grid. This study addresses the question which (set of) protocol(s) is best applicable for which functionality in different types of situations. To be able to do this, this study also identifies for each of these protocols which functionalities it supports and how it scores on interoperability, maturity, market adoption and openness.

This study has led to the following summary of use cases supported by the different protocols¹:

	OSCP	OpenADR	OCPI v0.4	IEEE 2030.5	OCPP	61850-90-8	OCHP	OCPI 2.1	OICP	eMIP	IEC 61851	ISO 15118
PROTOCOL	SMART CHARGING				CS ↔ CP		ROAMING				EV ↔ CP	
Authorize charging session			•		•		•	•	•	•		•
Billing					•		•	•	•	•		
EV Charging											•	•
Handle registration		•		•				•				
Manage grid	•	•		•	•	•						
Operate Charge Point					•	•						
Provide charge point information			•				•	•	•	•		
Reservation			•		•		•	•	•			•
Roaming			•				•	•	•	•		
Smart Charging	•	•	•	•	•	•	•			•	•	•

¹ O → Operating Charge Point using 61850-90-8: only the basics
 Smart Charging in OCHP: only OCHPdirect and only basics
 Smart Charging in eMIP: only 1 OEM (so only 1 car brand)

The protocol score on the properties of interoperability, maturity, market adoption and openness is summarized in the following overview:

	Version	Maturity	Interoperability	Market Adoption	Openness	Testing tool (dedicated / specific)	Certification (official / eshlab)
Smart Charging							
OSCP	1.0	Low	High	Low	Medium	No	No
OpenADR 2.0	1.1	High	Medium / High	Medium / High	High	Yes	Yes
OCPI	v0.4	Very low	Very low	Low	Low	No	No
IEEE 2030.5	2.0	High	Medium / High	Low	High	Yes	Yes
CS - CP							
OCPP	1.6	High	High	High	Medium / High	Yes	No
IEC 61850(90-8)	-	Medium	Low	Low	High	Unknown	Yes
Roaming							
OCHP	1.4	High	High	Medium / High	Medium	No	No
OCPI	2.1	Low	High	Low	High	No	No
OICP	2.1	High	High	High	Medium	No	No
eMIP	0.7.4	High	High	Medium	Low / Medium	No	No
EV - CP							
IEC 61851-1	-	High	High	High	High	Unknown	Yes
ISO / IEC 15118	-	Medium	High	Low	High	No	No

This study also confirms that many combinations of protocols are possible, a number of which are discussed in this study. No combination of protocols is considered a “silver bullet” for all current and future situations. However, some main conclusions that can be drawn are that:

- the next step for roaming protocols seems to be the addition / extension of smart charging functionality.
- a choice is to be made whether point-to-point protocols or a clearing house type of communication is to be pursued, or perhaps both.
- an important smart charging aspect of 15118 is the retrieval of the state of charge. In some cases, this information can also be retrieved via OEM platforms but only through specific, non-standardized interfaces. For the short term a next step in the protocols related to smart charging, could be the addition of connections to different OEM platforms for getting this state of charge using an open standard.

When looking at the current state of the protocols under consideration, it is recommended to put more work in the smart charging aspects of the existing roaming protocols and to take a next step in roaming platforms (e.g. connecting, merging). In order to accelerate the adoption of smart charging, the state of charge and time of departure are crucial pieces of information. For getting the state of charge it is recommended to focus on open protocols to include OEMs in the EV domain. In the longer term, the ISO / IEC 15118 protocol seems to be an alternative for this, this protocol however does not seem to be implemented in the short term. The first EV's with ISO / IEC 15118 basic functionality (“plug & charge”) are expected in mid-2018.

When the time of departure is needed, communication with the EV user might be necessary, either directly or via the EV (ISO / IEC 15118). A new protocol could be of use here, but this choice is left to the commercial parties in the EV market. If a protocol is desirable, an “open”

protocol should be preferred to avoid lack of adoption due to interoperability issues. When purely looking at protocols, communicating grid limits or dynamic prices is already possible. However, current legislation in most countries is not yet prepared for dynamic pricing or setting grid limits from a power system operator. It is recommended that this legislation is changed (perhaps even equalized) to make it possible to utilize the flexibility EVs have to offer to the energy transition.

Contents

1. Introduction.....	8
1.1 General.....	8
1.2 Intended audience	8
1.3 Versions.....	9
1.4 Definitions / abbreviations	10
2. Research questions	12
3. Scope	12
4. Approach	15
4.1 Use case based approach	15
4.1.1 Introduction.....	15
4.1.2 Reading guide	15
4.1.3 Example	15
4.1.4 High level use cases	16
4.2 Limitations to the approach.....	17
4.3 Interoperability	18
4.4 Market adoption	18
4.5 Maturity.....	18
4.6 Openness	18
4.7 Scoring EV related protocols.....	19
5. Protocol analysis.....	20
5.1 Smart Charging.....	21
5.1.1 Open Smart Charging Protocol (OSCP).....	22
5.1.2 OpenADR 2.0	24
5.1.3 Open Charge Point Interface protocol (OCPI v0.4)	28
5.1.4 IEEE 2030.5 (IEEE Adoption of Smart Energy Profile 2.0 / SEP2).....	30
5.1.5 Smart charging protocols overlap	35
5.2 Central System – Charge Point.....	37
5.2.1 Open Charge Point Protocol (OCPP).....	38
5.2.2 IEC 61850-90-8	41
5.2.3 Central system – charge point protocol overlap	42
5.3 Roaming	44
5.3.1 Open Clearing House Protocol (OCHP).....	45
5.3.2 Open Charge Point Interface protocol (OCPI 2.1)	48

5.3.3	Open InterCharge Protocol (OICP)	52
5.3.4	eMobility Inter-Operation Protocol(eMIP)	54
5.3.5	Roaming protocols.....	58
5.4	EV – Charge Point	60
5.4.1	IEC 61851-1	61
5.4.2	ISO / IEC 15118.....	62
5.4.3	EV – Charge Point protocols overlap	65
6.	Protocol discussion	66
6.1	Overview.....	67
6.2	EMSP – CPO communication	68
6.3	EV charging	70
6.4	Smart Charging.....	71
6.5	Protocol relevance for smart grid from a DSO perspective.....	74
6.6	Relation to home charging	75
7.	Conclusion and recommendations	77
7.1	Conclusion.....	77
7.2	Recommendations.....	78
Literature	81
	Protocol documentation.....	81
	Other context related documents.....	81
	Websites of protocol authors / publishers	82
Appendix A:	Future plans per protocol	0
Appendix B:	Protocol use case table.....	2

List of figures

FIGURE 1: DISTRIBUTION OF THE PROTOCOLS IN THIS STUDY	14
FIGURE 2: EXAMPLE USE CASE MODEL EXCERPT OF OCPP	16
FIGURE 3: USE CASE OVERVIEW OF OSCP PROTOCOL	23
FIGURE 4: USE CASE OVERVIEW OF OPENADR PROTOCOL	26
FIGURE 5: USE CASE OVERVIEW OF OCPI V0.4 PROTOCOL	30
FIGURE 6: USE CASE OVERVIEW OF IEEE 2030.5 PROTOCOL	34
FIGURE 7: USE CASE OVERVIEW OF OCPP PROTOCOL	39
FIGURE 8: TRAFFIC LIGHT CONCEPT (FROM [CCE2012])	43
FIGURE 9: USE CASE OVERVIEW OF OCHP PROTOCOL (EXCL. OCHPDIRECT)	46
FIGURE 10: USE CASE OVERVIEW OF OCHPDIRECT PROTOCOL	47
FIGURE 11: USE CASE OVERVIEW OF OCPI 2.1 PROTOCOL	51
FIGURE 12: USE CASE OVERVIEW OF OICP 2.1 PROTOCOL	53
FIGURE 13: USE CASE OVERVIEW OF EMIP PROTOCOL	56
FIGURE 14: SCHEMATIC COMPARISON OF ROAMING PROTOCOLS	59
FIGURE 15: USE CASE OVERVIEW OF ISO / IEC 15118 PROTOCOL	64
FIGURE 16: OVERVIEW OF PROTOCOLS AND MARKET ROLES	67
FIGURE 17: MORE COMPLEX VIEW OF PROTOCOLS	68
FIGURE 18: POINT-TO-POINT SETUP VS. CLEARING HOUSE SETUP	69
FIGURE 19: MULTIPLE CLEARING HOUSES SETUP	69
FIGURE 20: BASIC EV CHARGING	70
FIGURE 21: CONNECTED CAR MODEL	71
FIGURE 22: SMART CHARGING USING GIREVE PLATFORM	73
FIGURE 23: SMART CHARGING USING ISO / IEC 15118	73
FIGURE 24: SMART CHARGING BASED ON ISO / IEC 15118 WITH MINIMIZED ROLE OF EMSP	74
FIGURE 25: EXAMPLE SETUP INCLUDING (B/H)EMS	75

List of tables

TABLE 1: HIGH LEVEL VIEW ON SMART CHARGING PROTOCOLS	35
TABLE 2: HIGH LEVEL VIEW ON EV ROAMING PROTOCOLS.....	58
TABLE 3: OVERVIEW OF PROTOCOL FUNCTIONALITIES.....	77
TABLE 4: OVERVIEW OF MATURITY, INTEROPERABILITY AND MARKET ADOPTION	77
TABLE 5: FUTURE PLANS PER PROTOCOL	0

1. INTRODUCTION

1.1 General

This study presents a discussion of a selection of Electric Vehicle (EV) related communication protocols² and a comparison based on the functionality that is supported by those protocols. One of the goals of the discussion is to provide information about the functionality of the protocols. Based on the list of functionalities per protocol, an analysis is done on how protocols can be used in conjunction with each other and / or perhaps how protocols overlap. This is to provide information that can be used by others, for example for enabling standard harmonization or enabling grid and system interoperability. In some cases different combinations of protocols can be used to reach the same goal. Another aim of this study is to make clear which of these combinations are possible and would currently make the most sense. Although this study is not limited to distribution system operator (DSO) protocols, especially on the smart charging protocols, the primary view of their applications and use will be from a DSO perspective.

The comparison will not go into the details of the messages or data fields of the protocols, but will stay on the level of supported functionalities. This study is not meant to judge or criticize protocols. The analysis in this protocol study will compare the functionality but is not intended as a value judgment on the quality aspects of the protocols.

This report has been reviewed by a number of protocol experts (for some protocols even the original authors) to make sure the functionalities mentioned in this report are correct. As input we used the latest versions of the protocols, as they were available at the time of writing. See chapter 3 for the protocols in scope, including the versions used. Functionalities that are planned for new releases are not considered in this report.

1.2 Intended audience

This document is intended for people that have some prior knowledge of the EV domain, for example decision makers with some knowledge of EV / Smart Charging or people that already have knowledge of one or more protocols and need more clarity in the large amount of other protocols that are currently available. Besides providing clarity, this document also aims to provide context for the different protocols and how these can be used in conjunction with each other. When starting in the EV domain, it is recommended to first get a global overview of the EV domain and terminology. For a proper understanding of this study, such knowledge is required and assumed.

² The term protocol is used in a broad way in this study. So for example OpenADR specifies a datamodel including transport and security mechanisms. However, combined with the xsd's, this can be used to communicate and in this study this will be referred to as a "communication protocol" or simply "protocol".

1.3 Versions

Version	Date	Author	Remarks
0.1	9/7/2016	Patrick Rademakers Paul Klapwijk	First draft
0.2	9/19/2016	Paul Klapwijk	<ul style="list-style-type: none"> Processed the Review comments of Jonel Timbergen. Elaborated chapters 1-4.
0.3	10/04/2016	Paul Klapwijk	<ul style="list-style-type: none"> Version for review Patrick Rademakers
0.4	10/28/2016	Paul Klapwijk	<ul style="list-style-type: none"> Version after review Patrick Rademakers & Lonneke Driessen
0.5	11/10/2016	Paul Klapwijk	<ul style="list-style-type: none"> Version after review Arjan Wargers and incorporating information from J2847/1
0.6	14/12/2016	Paul Klapwijk	<ul style="list-style-type: none"> Version after (partial) review of: <ul style="list-style-type: none"> Patrick Rademakers Claus Amtrup Andersen Robert de Leeuw Richard Scholer James Mater Harm van den Brink Léon Huijsdens Klaas van Zuuren Max Dern Mourad Tiguercha Jean-Marc Rives Rolf Bienert
0.7	02/01/2017	Paul Klapwijk	<ul style="list-style-type: none"> Version after review of: <ul style="list-style-type: none"> Rolf Bienert Max Dern Klaas van Zuuren Robert de Leeuw Richard Scholer James Mater Added pictures by Marcel Nahapiet Added tables by Shapeshifter.nl
0.8	18/01/2017	Paul Klapwijk	<ul style="list-style-type: none"> Version after review Simon Schilling Added some input from IEC discussion. End review by Arjan Wargers
0.9	19/01/2017	Paul Klapwijk	<ul style="list-style-type: none"> Added cover by Shapeshifter.nl
1.0	20/01/2017	Paul Klapwijk	Version 1.0
1.1	24/01/2017	Paul Klapwijk	Minor changes

1.4 Definitions / abbreviations

Term	Definition
BRP	Balance Responsible Party
Clearing	Clearing is a term from the finance industry. In the EV market it refers to the process of exchanging information such as transaction information (“CDRs”) for billing (“settling”) and roaming purposes.
Clearing House	A Clearing House is an institution or system that facilitates (automatic) clearing.
Connector	A Connector is an independently operated and managed electrical outlet on an EVSE.
CPO	Charge Point Operator. Party that operates and maintains charge points.
DER	Distributed Energy Resources. “Distributed energy [...] is generated or stored by a variety of small, grid-connected devices referred to as distributed energy resources. DER systems typically use renewable energy sources, including small hydro, biomass, biogas, solar power, wind power, and geothermal power, and increasingly play an important role for the electric power distribution system” ³ .
DR	Demand / Response. This refers to “changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized ⁴ .” See paragraph 6.4 for a further explanation of the relation to EV and smart charging.
DSO	Distribution System Operator. A netoperator or gridoperator.
eMIP	eMobility Inter-Operation Protocol
EMSP / eMSP	E-Mobility Service Provider. Party that handles all communication and billing towards EV users. These roles of EMSP and CPO are not separated in all markets, in some countries these roles are filled in by the same party. However, this distinction is still relevant for enabling customers of party to use a charge point of another party.
ESI	Energy Service Interface
EV	Electric Vehicles that have battery energy storage (sometimes referred to as Battery Electric Vehicle, BEV). This includes PHEV (Plugin Hybrid EV).
EVSE	Electrical Vehicle Supply Equipment. The logical unit in a Charge Point that supplies electric energy via a Connector for charging. An EVSE can have one or multiple Connector(s).
Flexibility	Within the energy system this refers to the property that indicates to what extent adjusting generation and / or consumption patterns in reaction to an external signal (e.g. price signal) is possible. Within the EV domain flexibility more or less equals smart charging.

³ https://en.wikipedia.org/wiki/Distributed_generation

⁴ <https://www.ferc.gov/industries/electric/indus-act/demand-response/dem-res-adv-metering.asp>

IEEE 2030.5	The IEEE adoption of Smart Energy Application Profile 2.0 (SEP 2)
IP	Intellectual Property
OCHP	Open Clearing House Protocol
OCPI	Open Charge Point Interface
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer. Refers to EV manufacturers.
OICP	Open InterCharge Protocol
OpenADR	Open Automated Demand Response
OSCP	Open Smart Charging Protocol
PEV	Plugin Electric Vehicle
PV	Photovoltaics. This “covers the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry. A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power.” ⁵
Roaming	In the telecom industry roaming is the ability of users to make use of their phones/subscriptions beyond the limits of the network of their provider of choice. It also covers the agreements between providers to make this possible. In the EV domain roaming is very similar: this is what allows EV drivers charge their EV at charging stations that are not part of the charging network of their CPO using the same identification.
SEP	Smart Energy Profile
Smart Charging	According to [CCE2012] and [EUCL2015] the definition of smart charging is when charging an EV can be externally controlled (i.e. “ <i>altered by external events</i> ”), “ <i>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 and while meeting the mobility constraints and requirements of the user.</i> ”
TSO	Transmission System Operator

⁵ <https://en.wikipedia.org/wiki/Photovoltaics>

2. RESEARCH QUESTIONS

This study aims to answer a number of research questions. The first question is targeted at the functionality of the protocols, to give an overview of these and what these can be used for. Besides describing functionality, it is also useful to have a look at the maturity of the protocols and whether or not these are already used in the market. This leads to the following research question:

1. What functionalities are supported by the EV related protocols within the scope of this document (see chapter 3)?

Sub question: How do these protocols score on the following properties:

- a. Interoperability?
- b. Maturity?
- c. Market adoption?
- d. Openness?

Besides providing information, another aspect is how the protocols can be used and how the protocols can be used in conjunction with each other. This leads to the second research question:

2. In various situation⁶ what set of protocols is best applicable for what end-to-end functionality?

Finally, it is also important to determine how relevant the protocols are from a smart grid perspective. Since EVs can charge with relatively high power compared to other residential loads on Low Voltage (LV) level, possibly at the same time period at a specific LV cable, this can lead to new challenges for DSOs. This is because at many locations the current electricity grid is not prepared for / suitable for high EV adoption and the large power demand of these EVs (demanded simultaneous at a relatively short period of time). This leads to the final (sub) question:

Which of the protocols are useful in managing the grid operational impacts of high penetration of EV charging?

3. SCOPE

As indicated in the introduction, this study discusses a selection of Electric Vehicle (EV) related protocols. ElaadNL bases this selection on the practical market experience⁷ that it has accumulated over the past years, the protocols that it has encountered in the EV market and pilot projects that have been executed by ElaadNL and partners. Additionally, this study tries to make clear which combinations of protocols are possible to serve specific use cases (such as “smart charging”) and to what extent protocols are similar and/or overlap.

⁶ Situation in this case refers to for example the traffic light concept as referred to by, for example, the Smart Grid Coordination Group (CEN-CENELEC-ETSI, 2012).

⁷ Primarily in Europe.

The scope of this document concerns the following protocols:

Protocol	Version	Author / Maintainer	Year of publ.
PART I: Smart Charging			
Open Smart Charging Protocol (OSCP)	1.0	Open Charge Alliance	2015
OpenADR 2.0	1.1	Lawrence Berkeley National Laboratory and OASIS Energy Interoperation Technical Committee.	2015
Open Charge Point Interface (OCPI)	0.4 ⁸	eViolin	2014
IEEE 2030.5 / Smart Energy Profile (SEP) ⁹	2.0	IEEE	2013
PART II: Central System – Charge Point			
OCPP	1.6	Open Charge Alliance	2016
IEC 61850-90-8	n.a.	IEC	2015
PART III: Roaming			
Open Clearing House Protocol (OCHP)	1.4	Smartlab, ElaadNL	2016
Open Charge Point Interface (OCPI)	2.1	Nationaal Kennisplatform Laadinfrastructuur(NKL)	2016
Open InterCharge Protocol (OICP)	2.1	Hubject	2013-2016
eMobility Inter-Operation Protocol (eMIP)	0.7.4	GIREVE	2016
PART IV: EV – Charge Point			
IEC 61851-1	N.a.	IEC	2010
ISO / IEC 15118	N.a.	ISO / IEC	2013/2014

For each of these protocols an overview of the supported use cases will be described. Please see the description of the chosen approach in chapter 4. Each protocol is described in a separate paragraph which includes sections describing the maturity, interoperability, market adoption and openness of the protocols.

The communication protocols are divided in 4 parts. This division is primarily based on the different roles and systems in the market and how the protocols are positioned between these roles and systems. From an ElaadNL perspective, the DSO side of the EV domain, and therefore smart charging, is particularly interesting. However, smart charging and EV

⁸ Although this is an older version of the OCPI protocol, it is included in the overview, due to the fact that it is still widely used within the EV market. It is also often referred to as draft v4 or even 1.0 draft 4.

⁹ This protocol is officially referred to as IEEE 2030.5.

penetration also depend on the rest of the EV chain. Therefore these parts are also part of the practical research at ElaadNL and thus part of this study. Due to the fact that some protocols are quite generic, these might fit in more than one “part”. This is visualized in Figure 1.

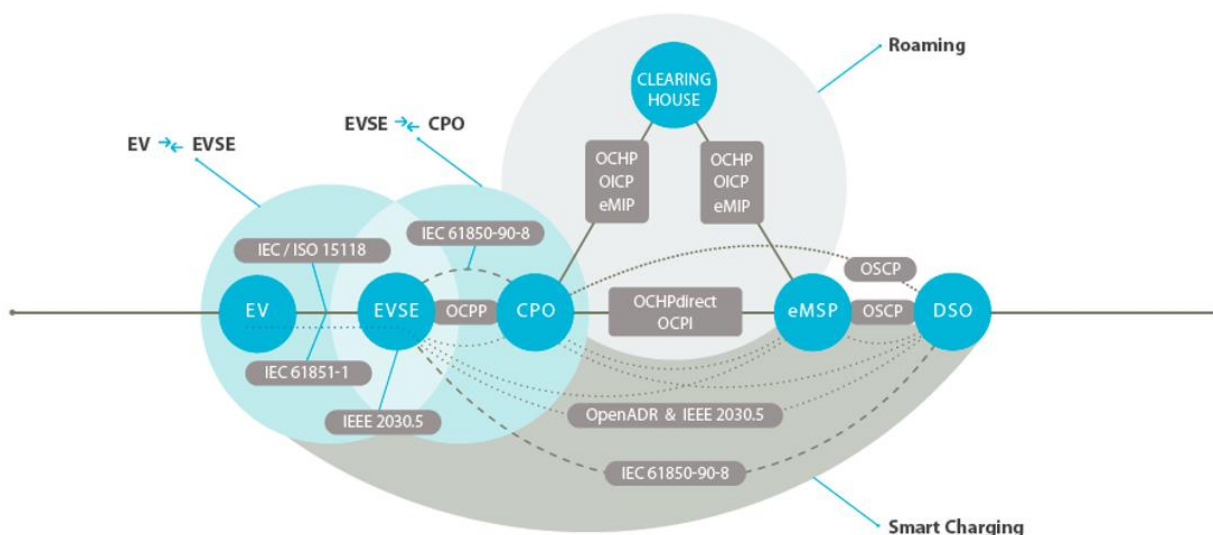


Figure 1: Distribution of the protocols in this study¹⁰

¹⁰ As you can see in the figure, IEC 61850-90-8 can be positioned both in the smart charging section as well as the EVSE <> CPO section. The choice was made to describe it in the EVSE <> CPO section.

4. APPROACH

4.1 Use case based approach

4.1.1 Introduction

As already indicated in the introduction of this document, the approach chosen for creating an overview of the protocols in scope, is an approach based on *functionalities*. Describing the functionality supported by the protocols is done by looking at the *use cases* that are supported by these protocols. Usually in software development, use cases are used to systematically and exhaustively describe the functionality of a system that can be further detailed in scenarios. In this study use cases are *not* used to describe *systems*, but *functionalities that are supported by a protocol*. Furthermore, the use case model is elaborated with more high-level use cases (like “*Billing*” and “*Roaming*”). The use case based approach can be considered a bottom up approach, which provides a, to some extent, systematic way to perform a neutral comparison.

4.1.2 Reading guide

This document is aimed at multiple audiences. For some of the more extensive protocols, the use case based approach will lead to large diagrams. Therefore, for each protocol a use case diagram is created, including a short summary of the main functionality. When reading this document, it should be kept in mind that the diagrams are only for expert readers or people that want to know more details on a specific protocol (exact functionalities, what role can execute what functionality etc.). When reading this study to get an overview of the available protocols and main functionalities, the diagrams can be skipped and the summaries should suffice. After each “part” of the document, a separate chapter is added to discuss and compare the protocols including overlap.

4.1.3 Example

To clarify the approach, this is illustrated by the following example:

Figure 2, which is an excerpt from the OCPP use case diagram, shows that the actor CPO can use the OCPP protocol to “*Execute Smart Charging commands*” (which results in an information flow to a charge point). This use case is “typed” as an OCPP use case (marked with <<OCPP Use Case>>). However, to be able to derive overlapping or complementary protocols, the use case model is extended to higher level use cases. The diagram indicates that “executing Smart Charging commands” is part of “*Schedule based charging*”. This is a more specific type of “*Managing power consumption of a charge point*”, which in turn is a more specific type of “*Decreasing / increasing power consumption of individual devices*”.

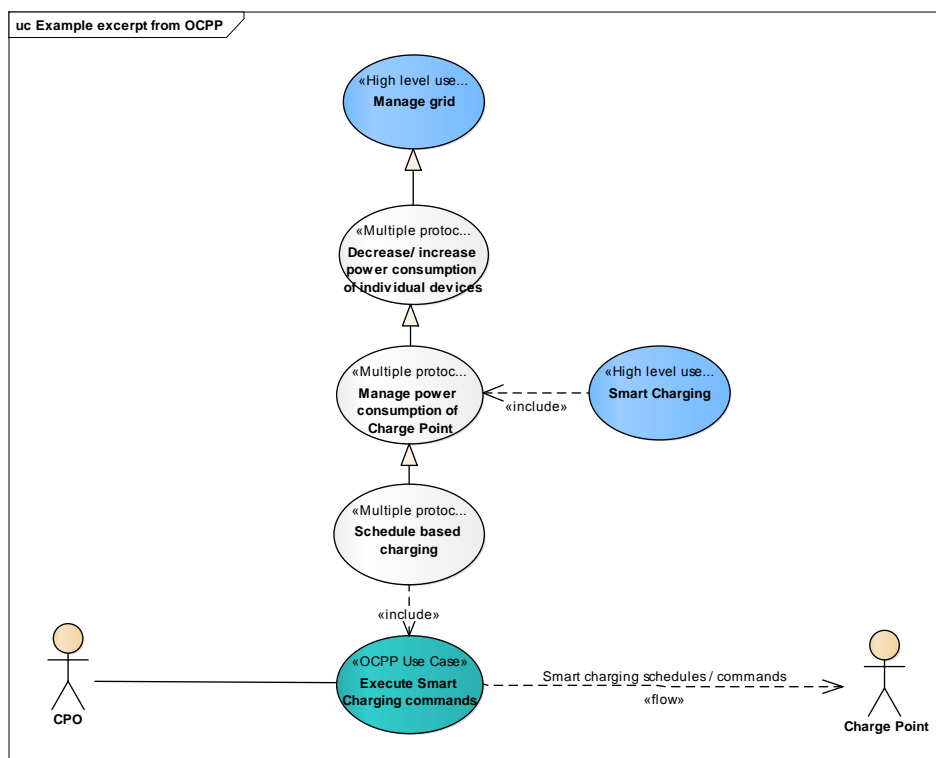


Figure 2: example use case model excerpt of OCPP

These last 2 use cases are marked as “Multiple protocol” use cases, which indicates that these use cases are also (partly) covered by other protocols (in this specific case: OpenADR, OCPI and OCHP). Overlapping or complementing functionality is not easily visible by looking at the different diagrams. Therefore an overview of the use cases and the protocols that are applicable for these use cases is added in Appendix B: Protocol use case table.

On a higher level a number of Use cases are defined, such as “Billing”, “Operate Charge Point”, “Roaming”, “Smart Charging”, etc. Finally an overview of use cases will be made, including the protocols that are applicable for these use cases. Furthermore, overlap between protocols will become visible and also examples will be given of sets of protocols that can be used to fulfill a high-level use case.

4.1.4 High level use cases

The high level use cases that are considered in this study are the following:

Use case	Definition
Authorize charging session	In this study this involves allowing a token / identification to charge at a charge point.

Billing	The standard definition for billing is “ <i>the process of sending an invoice to customers for goods or services</i> ” ¹¹ . In this study this mainly involves exchanging Charge Detail Records (CDR’s).
EV charging	In this study this refers to the actual charging (energy flowing), not the administrative process surrounding it.
Handle registration	In this study this involves handling communication registrations / subscriptions. In some protocols this happens manually, in some protocols automatically. In case this is part of the protocol and thus a possibility to do this automatically, this is described with this use case.
Manage grid	In this study this refers to being able to control a charge point, both the amount of capacity that is demanded from the grid as well as other factors.
Operate charge point	In this study this involves being able to operate a charge point from a back office. This includes upgrading firmware, setting a charge point to available or unavailable / reserved / error, configuring charge points and repairing faults.
Provide charge point information	In this study this involves providing information about a charge point. This can be both static (e.g. location) as well as dynamic (availability) information.
Reservation	In this study this involves functionality that is needed for an EV user to reserve a charge point.
Roaming	In this study this involves exchanging information (primarily authorization) to enable EV users to charge using 1 token at different charge points of different EMSPs and CPOs
Smart Charging	In this study this involves all forms of smart charging (for whatever reason), ranging from simply being able to stop / restart charging during a charging session to schedule based charging.

4.2 Limitations to the approach

As with every approach, our approach as described in 4.1 also has some drawbacks. The main drawback is that this approach is not perfectly applicable for all protocols. Some of the protocols discussed are quite generic while other protocols are developed for a very specific situation / use case. This makes it somewhat harder to compare different types of protocols, however, it seems the best way to have a systematic and neutral comparison.

Another drawback concerns the different granularity of the protocol messages. To prevent getting lost in minor details, the use case model is based on use cases / terminology that sometimes unavoidably abstracts away some of the message details. Despite these limitations,

¹¹ See for example Wikipedia.

we consider a use case based approach as the most neutral and exhaustive way to describe the protocols and the best way to do a comparison study. This avoids the limitation of not implemented parts of protocols in systems or environment specific use of a protocol.

4.3 Interoperability

Interoperability is considered on different levels. Besides technical interoperability, *syntax* and *semantics*, another level of interoperability is considered: *expected / desired behavior*. If behavior is specified in more detail, this usually means that interoperability is higher. However, this usually also means that a protocol is less generic, which makes it less applicable in other environments than it was originally intended for. Other factors that influence the interoperability is how *clear* the specification is, the amount of optional elements¹², the possibility to implement one functionality in multiple ways and the availability of “interop events”. The focus will be less on the commissioning part of protocols, but more on the effort when “replacing” the other side.

The factors mentioned here, will together determine the interoperability score.

4.4 Market adoption

Market adoption is based on the current number of users, companies or countries that use the protocol. This will give an impression of the market adoption, but since the markets for EV and flexibility are currently emerging / in development, it is not possible to use extensive statistics and number of users / countries / companies to give a detailed overview of the market adoption of protocols. Many protocols in this study are “open” (see below) and do not (yet) have certification in place, which means that it is not always known to the authors of a protocol whoever is actually using their protocol. Therefore, this score will be based more on experience and estimations than hard numbers.

4.5 Maturity

As with market adoption, the maturity of a protocol is hard to determine in detail. In this study, the score will be based on: number of releases, time in use, market adoption, certification possibility (at an official test laboratory), availability of a testing tool (dedicated / specific), availability / detail of the (test) specification and the possibility to implement only basic / relevant parts.

4.6 Openness

For scoring the protocols on the property “openness”, we assess whether the standard has been developed by an accredited standards organization, whether it is subject to intellectual

¹² Please note that optional elements do not necessarily mean that a protocol is multi interpretable / has a lack of precision.

property¹³ (IP) licensing and/or royalties or other implementation/usage restrictions and whether the specification is publically accessible at no (or minimal) cost.

4.7 Scoring EV related protocols

In this study, scoring the different properties of the protocols is done on a (very) low / medium / high scale. This scale is used while taking into account the maturity of the EV domain. This means that a “high” score on, for example, “maturity” is not to be compared to the maturity of standards like the WiFi standard. This would limit the scale due to the fact that the EV market is still an upcoming market. A “high score” should thus be interpreted as a “high score within the EV domain”.

¹³ To the knowledge of the author and reviewers.

5. PROTOCOL ANALYSIS

This chapter gives an overview of the different protocols. This chapter is divided in 4 parts:

1. Smart Charging
2. Central System – Charge Point
3. Roaming
4. EV – Charge Point

Each protocol will be described in a number of sections, containing an introduction, a use case overview and paragraphs about maturity, interoperability, market adoption and openness.

Every part will cover at least 2 protocols and will be concluded with a paragraph about the overview of the differences between the protocols and the overlap (if any).

5.1 Smart Charging

“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 AND WHILE MEETING THE MOBILITY CONSTRAINTS AND REQUIREMENTS OF THE USER.”

[EUDEL2015]

5.1.1 Open Smart Charging Protocol (OSCP)

Introduction

The Open Smart Charging Protocol communicates forecasts of the available capacity of the electricity grid to other systems. This protocol has first been created by Dutch DSO Enexis and EMSP¹⁴ / CPO GreenFlux but has been transferred for further development to the Open Charge Alliance.

The protocol is based on a budgetary system where client systems can indicate their needs to a central system, which guards against overuse of the grid by handing out budgets per cable. If a system requires more it can request more, if it requires less it can hand back part of its budget, to be available for other systems.

OSCP has no direct relationship with charge points, the protocol is by design more generic. It can, in principle, be used for allocation of capacity in general (energy, bandwidth, euro's etc.) from a higher level system to a lower level system. However, the naming is quite DSO specific. The exact reason why a client system manages power is out of scope of the protocol.

Use cases supported by OSCP

Figure 3 illustrates the use cases that are supported by OSCP. The use cases supported by OSCP are currently quite specific for the scenario where a DSO manages grid capacity by distributing capacity forecasts i.e. to either EMSP's or CPO's. The high-level use cases as listed in paragraph 4.1.4 supported by OSCP are:

- Smart charging (capacity based)
- Manage grid

In more detail, it includes:

- Handing out capacity budgets
- Managing grid capacity using these budgets
- Smart charging by communicating capacity *forecasts*

¹⁴ See 0 for the definition of EMSP and the relation to a CPO.

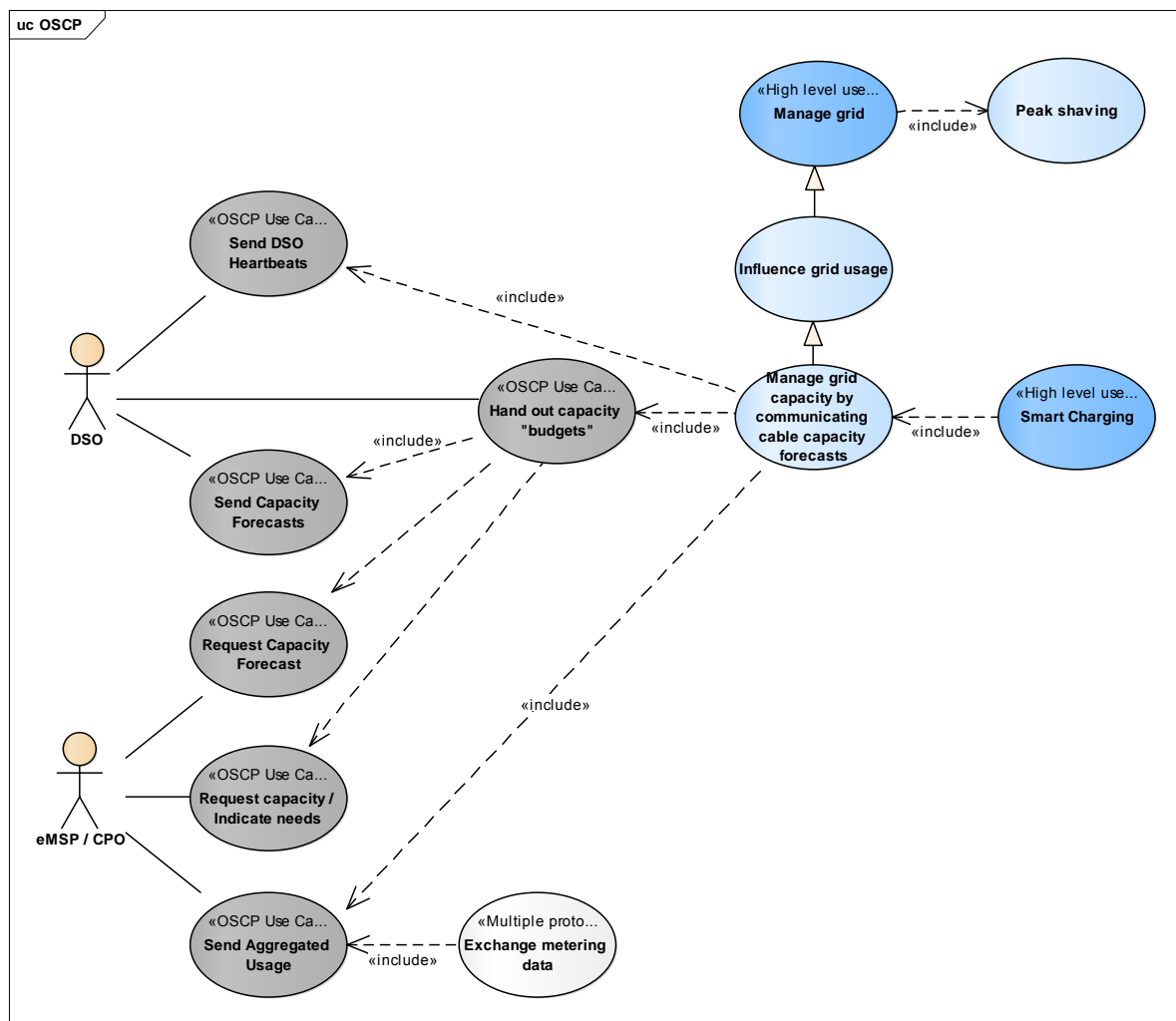


Figure 3: Use case overview of OSCP protocol

Maturity

The current OSCP version is 1.0 and dates from 2015-04-09. This is the first public version of the protocol. The level of detail of the specification is moderate, no test specification is available. Furthermore, the specification does not mention whether or not all parts of the standard are to be implemented, although this is suggested by the (behavior) scenario which is explained in the specification. No plans for new versions / releases from the Open Charge Alliance are known. Currently certification is not possible, no testing tool is available.

Based on the above, the maturity of the protocol is classified as low.

Interoperability

The protocol describes a quite specific use case including the prescribed behavior of the actors that are involved. The messages are defined in a strict WSDL (schema). It is not specified which messages are mandatory and which are not. The interoperability between parties on a technical

level is high, the behavior level it is classified as medium / high. The overall interoperability is classified as high.

Market adoption

OSCP version 1.0 is in use at fewer than ten locations in the Netherlands for smart charging based on available capacity (for a combination of building and parking garage). No active development takes place. It is currently used at 2 DSO's in the Netherlands and (at least) one CPO. Several parties have shown interest in the protocol, but no other locations are known where OSCP is actively used.

The market adoption is therefore classified as low

Openness

The OSCP protocol is publically available at no cost from the website of the Open Charge Alliance, containing no IP besides the copyright by the Open Charge Alliance (since OCA is the author). However, OCA is not considered an accredited standards organization. The openness is therefore classified as medium.

5.1.2 OpenADR 2.0

Introduction

The Open Automated Demand Response standard is a (dynamic) Demand Response protocol, developed by the United States (U.S.) Department of Energy's Lawrence Berkeley National Laboratory (LBNL) since 2002, formally published, as a standard by the international standards development organization, the Organization for the Advancement of Structured Information Standards (OASIS) Energy Interoperation Technical Committee and maintained by the OpenADR Alliance. The OpenADR Alliance (US-based) has members from all over the world, including grid companies, research institutes and commercial component and infrastructure companies. According to the specification, "*the development of [...] OpenADR began in 2002 following the California electricity crisis*".

As the name implies, the protocol is aimed at automating demand response communication, it supports a system and / or device to change power consumption or production of demand-side resources. This can, for example, be done based on grid needs, either by means of tariff and / or incentives or emergency signals that are intended to balance demand to *sustainable* supply.

Use cases supported by OpenADR

In Figure 4 (see next page) the use cases that are supported by OpenADR are visualized. The high-level use cases as listed in paragraph 4.1.4 that are supported by this protocol are:

- Handle registrations (registering a virtual end node at a virtual top node¹⁵)
- Manage grid
- Smart charging

¹⁵ The terminology in OpenADR is generic. Publishers of information are called virtual top nodes (VTN), subscribers to information are virtual end nodes (VEN). There could be any amount of VTN/VEN pairs based on market needs.

In more detail it can also be used for

- Sending price and load control signal, which can be used for decreasing / increasing power consumption of individual devices, which is a form of managing a (smart) grid.
- Sending reports. In the EV context this can for example be standardized metering data from a charge point (for example for monitoring and validating performance), charge levels (in case of V2G), use times for forecasts etc.

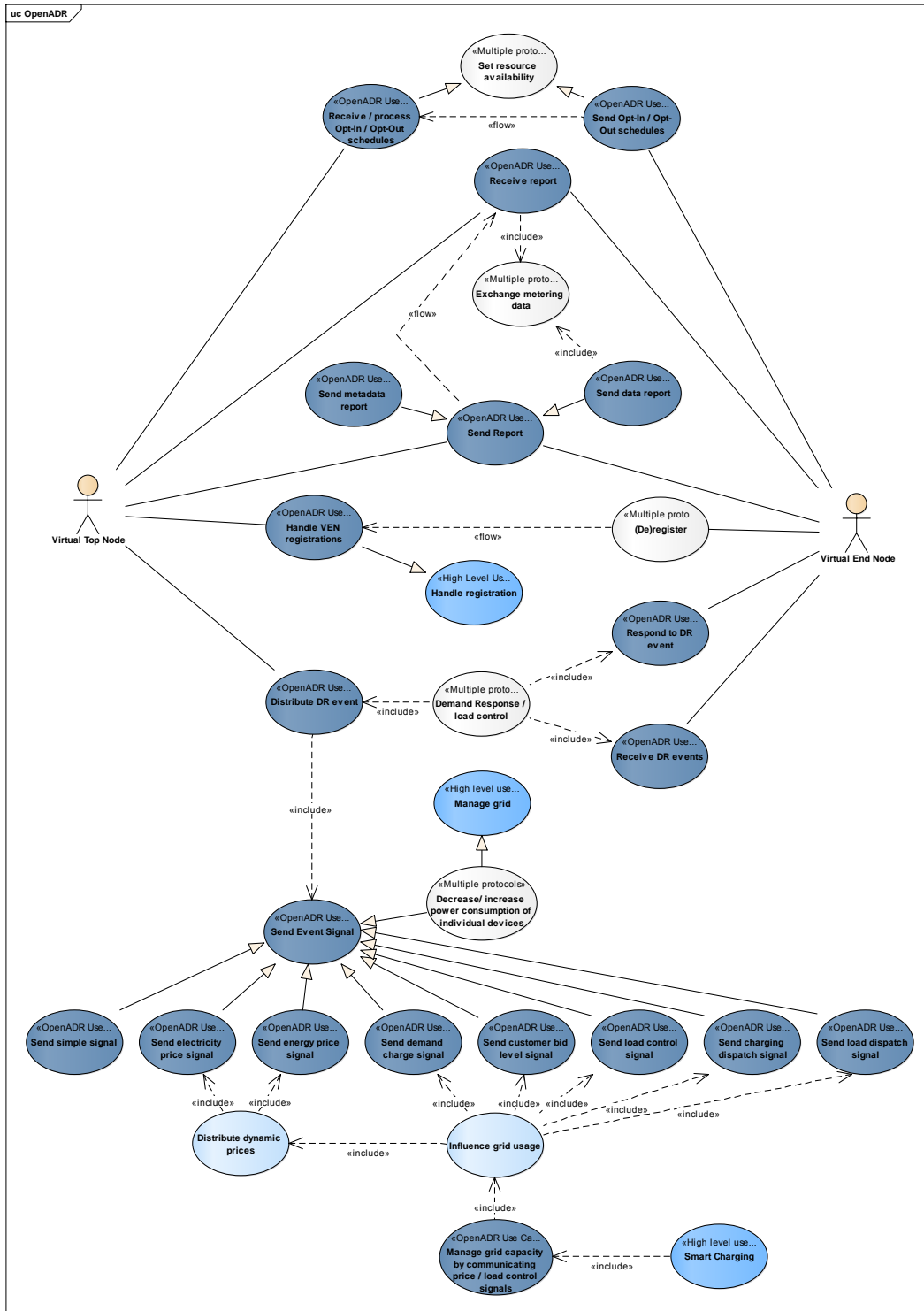


Figure 4: Use case overview of OpenADR protocol

Maturity

The current version of the OpenADR 2.0b standard is 1.1 (with minor updates to the version 1.0 published in 2013). The OpenADR Alliance, which was formed in 2010, supports the management of a formal standard published by OASIS. The OpenADR standard is divided into several “profiles” (A and B, where the A profile is a sub-set of B profile, hence “2.0a” and “2.0b”) and does not only describe the messages in the protocol, but also provides registration, the transport protocol and security. The specification defines which parts of the standard are to be implemented to be OpenADR compliant. There are (members only) on-site interop tests in an authorized OpenADR Alliance test lab or other suitable facility. Furthermore members can purchase an Alliance testing tool that is identical to the test harness used by the authorized certification test labs to complete the certification testing.

Based on the above, the maturity of the protocol is classified as high.

Interoperability

The OpenADR alliance organizes interoperability test events, provides a testing tool and certification. Testing and certification includes a number of mandatory cases that are tested and certified to ensure that any client can communicate when installed and enrolled. This means that the technical interoperability (both syntax as well as semantics) is high.

The protocol is quite generic (due to the nature of DR programs), which means that it can be used in a wide range of areas. Since the DR program message content is an outcome of a specific implementation, this genericity makes it impossible to describe the exact signal content and behavior for interoperability with every program. To limit the variability of the implementation scenarios, the OpenADR Alliance has published A “DR Program Guide” that sets out to harmonize the programs and add additional certification options. Basic EV charging is considered. On the behavior level the interoperability is therefore classified as medium.

Market adoption

According to the website, the alliance has 130 member companies and the database of OpenADR certified products contains over 100 products. The standard has been adopted for use in the US, South Korea, Japan, and Canada and is under consideration in Europe and elsewhere in the world. Based on this, the market adoption of OpenADR is medium / high.

Openness

The OpenADR protocol specification profiles A and B are publicly available at no cost from the website of the OpenADR Alliance. The standard does not have any IP associated with it. The alliance is not considered an accredited standards organization but the OpenADR 2.0 A and B profiles are based on a standard called Energy Interoperation that has been formally adopted as an international standard by the OASIS standards organization. In addition, the IEC has approved the OpenADR 2.0b specification as a “Publicly Available Specification” (PAS) as a basis for a new IEC commission standard to be developed.

The openness is therefore classified as high.

5.1.3 Open Charge Point Interface protocol (OCPI v0.4)

Introduction

The Open Charge Point Interface protocol is designed for exchanging information about charge points. The protocol is for exchanging information between the market roles of Charge Point Operator and e-Mobility Service Provider. These roles are not separated in all markets. In some countries these roles are filled in by one party. However, these split up roles are still relevant for enabling customers of one party to use a charge point of another party (“roaming”).

The OCPI protocol originates from the Dutch EV market, where, starting in 2009, a number of CPOs and EMSPs (collaborating under the name eViolin) together with ElaadNL, created a first version of a protocol for exchanging information concerning charge points. Eventually in 2014 this resulted in the development of OCPI. Version 0.4 (also called “draft v4” and “1.0 draft 4”) is an *old* version of the OCPI protocol. However, despite being far from perfect / finished, is in use at several market parties within the Dutch energy market. For this reason it is also taken into account in this study. This version is not compatible in any way with the newer version 2.1 discussed later in this study (total redesign).

Use cases supported by OCPI

In Figure 5 the use cases which are supported by OCPI are visualized. The high-level use cases as listed in paragraph 4.1.4 that are supported by this protocol are aimed at a combination of smart charging and roaming:

- Providing charge point information
- Reservation
- Smart charging
- Authorizing charging sessions
- Roaming

In more detail:

- Providing charge point information concerns information about location and tariff.
- Information that can be exchanged concerns smart charging, reservations and authorization tokens.

Maturity

The version 0.4 of the OCPI protocol is a draft version that was not really “finished” before it was taken into use. The level of detail of the specification is low, no test specification is available. Furthermore, the specification does not mention whether or not all parts of the standard are to be implemented. Newer versions of the protocol are being developed within “NKL Nederland”, a Dutch cooperation of organizations involved in public charging. Certification is not possible. No testing tool is available.

Based on the above, the maturity of this version of the protocol is classified as very low¹⁶.

Interoperability

Due to the low maturity of the protocol, the interoperability is very low. To enable communication between 2 systems using OCPI v0.4, several additional bilateral details have to be decided on.

Market adoption

The version of the OCPI protocol under consideration is only in use by a number of Dutch market parties. The market adoption of the protocol is therefore considered as low.

Openness

The OCPI v0.4 protocol is not publically available from the website of NKL Nederland. Copies of the protocol specification however do circulate and the protocol can be used no cost, it contains no IP. NKL Nederland is not considered an accredited standards organization.

The openness is therefore classified as low.

¹⁶ Development by NKL has resulted in version 2.0 (1.0 was skipped).

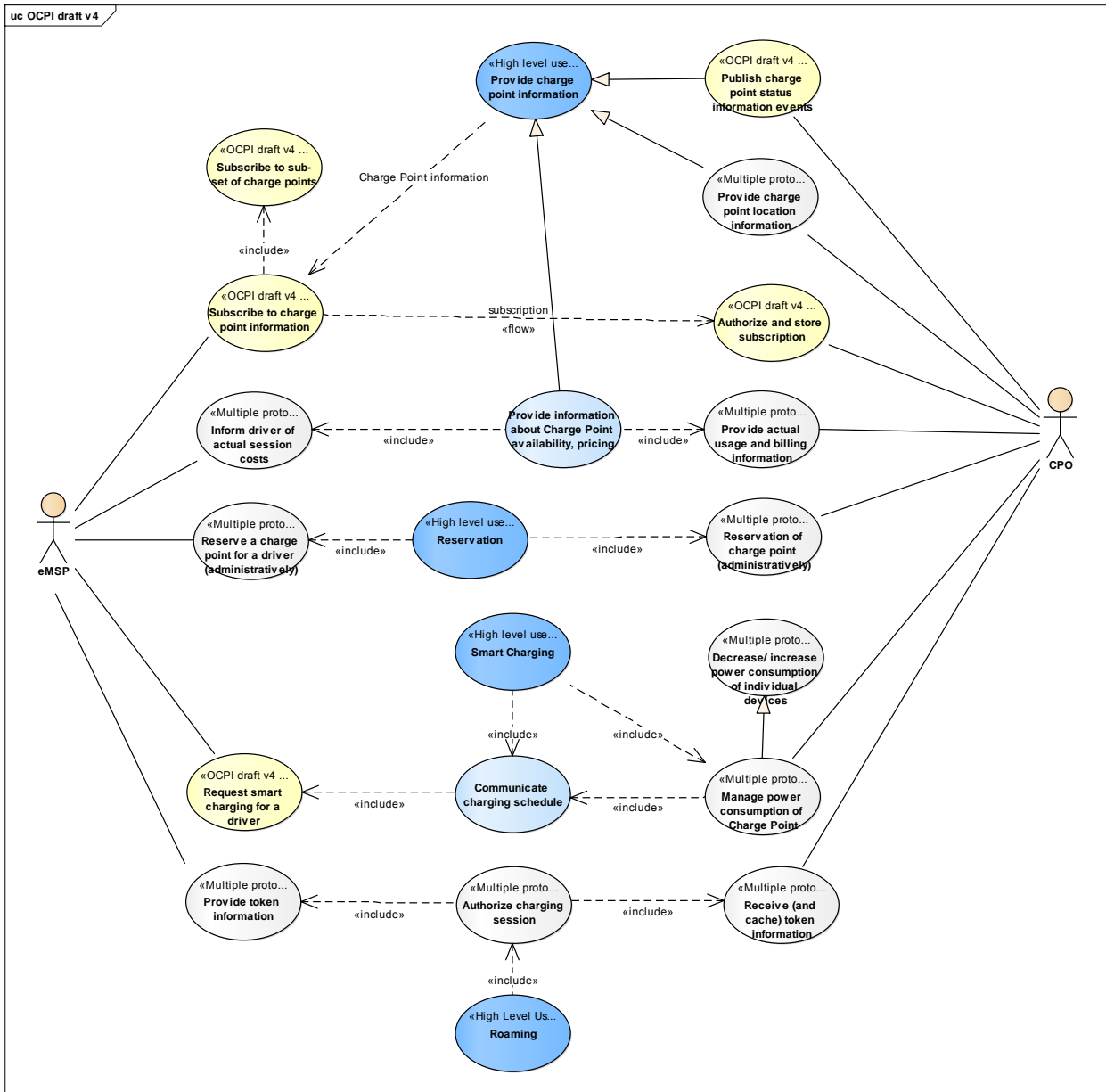


Figure 5: Use case overview of OCPI v0.4 protocol

5.1.4 IEEE 2030.5 (IEEE Adoption of Smart Energy Profile 2.0 / SEP2)

Introduction

The IEEE 2030.5 protocol (the IEEE adoption of Smart Energy Application Profile 2.0 / SEP2) is a protocol aimed primarily at in house smart grid solutions, also called “home energy management” via internet enabled devices (both wired as well as wireless). The protocol is

based on the IEC 61968 common information model and the IEC 61850 information model for DER. The protocol originates from the ZigBee Alliance and is a successor to the Zigbee Smart Energy Protocol V1. In 2012, the Consortium for SEP 2 Interoperability (CSEP) was formed by the WiFi, ZigBee, HomePlug and Bluetooth Alliances to specify certification requirements. The Consortium was disbanded in early 2016 (see for more details).

In 2013 the protocol has become a standard within the IEEE.

Use cases supported by IEEE 2030.5

The IEEE 2030.5 protocol is a broad protocol and describes a number of functionalities and also gives hints for which types of devices / systems this functionality is meant. In Figure 6 a complete overview of the (sets of) use cases is given, which are called “function sets” in IEEE 2030.5. To avoid misunderstandings when comparing with other protocols in this study, the terminology of IEEE 2030.5 is not adopted in the diagram.

The IEEE 2030.5 protocol is focused on communication from the utility to an Energy Service Interface (ESI). This ESI, in a house is the utility Trust Source that the EV would communicate with. The ESI could also be the Energy Management System (EMS) for a home to one or more EVSEs and other home loads, or any public EVSEs for smart/optimized charging of multiple EVs connected to multiple EVSEs.

According to the specification, the following sets of use cases could be applicable for electric vehicles. Part of this is based on the J2847/1 specification, which describes “*Communication for Smart Charging of Plug-in Electric Vehicles using Smart Energy Profile 2.0*”:

- Demand Response / Load Control. The specification refers to “devices that support load control”. This could be interpreted as EVs (or a combination of charge point and EV). According to the [SMC-SEP2013] specification this is primarily targeted at the smart charging use case “*Direct Load Control Programs*”.
- Exchanging metering data. Translated to EV, this functionality could be used for exchanging metering data between charge point and CPO. According to [SMC-SEP2013], this can be applicable in any smart charging use case, but is required for the use case “*Time-Of-Use (TOU) Rates / Tariffs / Programs (Load Shifting)*”
- Providing tariff information (in the IEEE 2030.5 specification this is called “Pricing”). This is used in three use cases:
 - “*Time-Of-Use*” (months / years ahead)
 - “*Critical Peak Pricing*” (day ahead) and
 - “*Real Time Pricing*” (minutes ahead).
- Sending text messages. This functionality for sending text messages can be used for “text messaging display devices”. Translated to the EV domain, this could be used for charge points that have a display.
- Providing actual usage and billing information. This concerns providing consumption, costs or cost / consumption targets from a service provider to an end device. For EV this could be from EMSP / CPO to charge point (for example for “*real time pricing*”).
- Prepayment, this functionality concerns delivery of a service based upon outstanding credit or debt. In case of EV charging this could be prepaid charging at a charge point.
- Energy flow reservation. This functionality is targeted at devices that use large amounts of energy (PEV’s and EVSEs are explicitly mentioned). This could be used by DSOs as

an input for managing capacity in the grid (“*Optimized Energy Transfer Program*”). Since this is different from the reservation definition as used in this study, the terminology is not “Reservation” as the function set is called in the IEEE 2030.5 specification.

The vehicle would send initial information to the utility on Time Charge Is Needed (TCIN) or when the vehicle is expected to be used the next time. This can be combined with Demand Response / Load Control and Pricing function sets to determine an optimum (use energy at lower price and only use an amount within the limit at that site).

- Manage DER. This functionality concerns both generation as well as storage. Electric vehicles are mentioned here explicitly as an example of storage.

Besides these functionalities, separate documentation is available which describes how IEEE 2030.5 can be used for smart charging PEVs.

This results in the high-level use cases as listed in paragraph 4.1.4:

- Smart charging
- Manage grid
- Handle registrations

Maturity

The IEEE 2030.5 protocol is standardized within the IEEE. The protocol is divided in several “function sets” and not only describes the messages in the protocol, but also has an extensive description of registration, discovery, the transport protocol and security. Furthermore, the specification contains sequence diagrams including message examples for a number of use cases.

The specification itself does not mention which parts of the standard are to be implemented for certification. The CSEP consortium qualified a set of test tools to implement certification of devices to the “CSEP Version 1.0 Test Specification” (in December 2013). The consortium was disbanded in early 2016. The test tools are available and used in an IEEE 2030.5 Conformance Test Program by two Nationally Recognized Testing Laboratories in the US and Korea (NTRL)¹⁷¹⁸.

Based on the above, the maturity of the protocol is classified as high.

Interoperability

The IEEE 2030.5 protocol is an IP-based protocol that is independent of the underlying physical transport. It uses the IEC 61968 data model for most of its semantics. The protocol adopts the IEC 61850-7-420 logical node classes for DER components and anticipated extensions to IEEE 2030.5 are intended to be made consistent with IEC 61850 extensions for DER. It consists of an xml schema and a description how messages are to be sent, including message examples. CSEP conducted dozens of industry interop events for IEEE 2030.5 devices as a follow-on to

¹⁷ Both NRTL’s, QualityLogic and UL and TTA (Korea), are internationally recognized.

¹⁸ Negotiations are in process to establish the first formal industry IEEE 2030.5 certification program with a focus on DER applications.

multiple events conducted by the Zigbee Alliance. This makes the technical interoperability (both syntax as well as semantics) high.

The protocol is quite broad and the function sets are defined in a generic way (client can be a thermostat, but also a PEV) which means that it can be used in a wide range of areas. This genericity makes it impossible to describe exact behavior. On this level the interoperability is therefore classified as medium.

Based on the above, the interoperability of the protocol is classified as medium / high.

Market adoption

Multiple companies and research organizations in the US and Korea have developed or are developing IEEE 2030.5 implementations for research and demonstration purposes. There are several commercial quality implementations and robust test and certification test tools available in the market. Two test labs are offering an IEEE 2030.5 Conformance Test program and an industry certification program is in development. However, the current implementations of IEEE 2030.5 are used in research projects and, to our knowledge, no production implementations currently exist. The pricing and Demand Response / Load Control function sets have been used in the Smart Energy Profile 1.x protocol (predecessor of IEEE 2030.5) for decades by utilities for load control using SEP1.x.

Based on the above, the market adoption is classified as low.

Openness

The IEEE 2030.5 protocol is publically available from the website of IEEE. The protocol can be bought at limited costs, it contains no IP. IEEE is considered an accredited standards organization.

The openness is therefore classified as high.

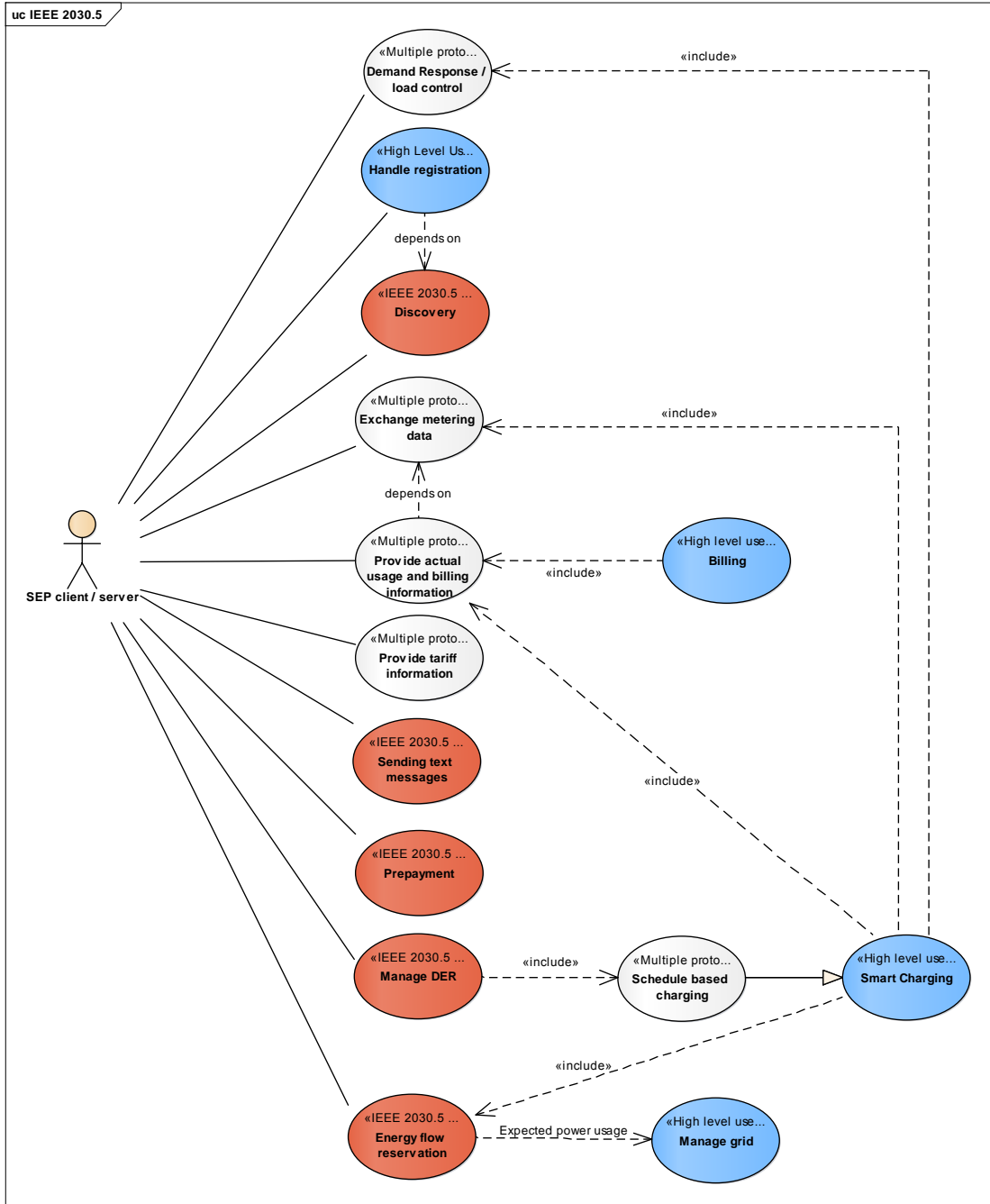


Figure 6: Use case overview of IEEE 2030.5 protocol

5.1.5 Smart charging protocols overlap

When considering the protocols in paragraph 5.1, the functionality that links them for EV, is the smart charging functionality. However, the protocols under consideration are quite different, which becomes clear when looking at the supported use cases on a high level (Table 1).

Table 1: High level view on smart charging protocols

	OSCP	OpenADR	OCPI v0.4	IEEE 2030.5
PROTOCOL	SMART CHARGING			
Authorize charging session			•	
Billing				
EV Charging				
Handle registration		•		•
Manage grid	•	•		•
Operate Charge Point				
Provide charge point information			•	
Reservation			•	
Roaming			•	
Smart Charging	•	•	•	•

The use cases supported by OCPI draft v4 are not only aimed at smart charging, but also at roaming. In this sense the protocol is broader than the OpenADR and OSCP protocols. However, it is a draft protocol, which is not described fully and is completely revised in the follow up version, which means that it is not useful to include it in the comparison of the other smart charging protocols. When new versions of OCPI will support smart charging again (version 2.1 does not, see chapter 5.3.2), it seems more appropriate to include the protocol in the comparison again.

When looking at OSCP, IEEE 2030.5 and OpenADR, it is clear that OpenADR is more mature. OpenADR also seems to have the highest market adoption. OpenADR and IEEE 2030.5 can be applied in a much broader range of demand response scenarios than OSCP, whereas OSCP is specifically for 1 situation. OSCP is only targeted at forecasting capacity (“capacity based smart charging”). IEEE 2030.5 is broader than OpenADR, even when primarily focusing on electric vehicles, the set of functionalities is larger than in the OpenADR set. OpenADR supports (among others) price signals and load control signals. The other IEEE 2030.5 functionalities, primarily aimed at communication with in home devices are out of scope of this study.

The specific nature of OSCP combined with the explicit description of the behavior in the specification, makes it easier to implement. The more generic nature of OpenADR gives rise for needing additional specifications when the protocol is applied in a specific scenario / market situation. When looking at the messages it seems that it might be possible to translate OSCP messages in OpenADR messages, but again: without additional behavior specifications it does not seem to be a ready alternative for the current implementations.

When looking at the smart charging protocols under consideration, these could be interesting from the point of view of a DSO. However, dynamic pricing or setting grid limits can only be done when this is legally binding. Currently this is not the case in most markets, legislation is not yet prepared for this. In most countries however the opportunity exists for research and experimenting. This offers the possibility to explore applying the protocols discussed in this paragraph.

5.2 Central System – Charge Point

5.2.1 Open Charge Point Protocol (OCPP)

Introduction

The Open Charge Point Protocol (OCPP) has been designed and developed to standardize the communications between an EV charge point (also known as a charging station or charging equipment) and a central system, which is used for operating and managing charge points. The communication protocol is open and freely available to ensure the possibility of switching from charging network without necessarily replacing all the charging stations or significant programming, including their interoperability and access for electric grid services. The protocol is intended to exchange information related to transactions and for operating a charge point including maintenance. The version under consideration (1.6) can also be used for schedule-based EV charging.

OCPP started out as an initiative of ElaadNL, a collaborative foundation created by a number of Dutch grid operators and the first version was published in 2009. In the beginning of 2014 development and maintenance of the protocol has been transferred to the Open Charge Alliance (OCA). The OCA has an international board of directors, and widespread global membership that including grid companies, research institutes, charge point manufacturers and commercial software and hardware companies. The OCPP has become the de facto open standard for charger to network communications in many countries, including in Europe and parts of the U.S. The OCPP version 1.6 that has been developed by the OCA, was made available to the formal standards development organization, OASIS, as the basis for the development of the next version (2.0). The OASIS OCPP technical committee had over 60 members from over 8 countries supporting its formal standardization until the committee was closed by OASIS¹⁹.

Use cases supported by OCPP

In Figure 7 (see next page) the use cases that are supported by OCPP are visualized. The high-level use cases as listed in paragraph 4.1.4 that are supported by this version of the protocol are:

- Authorize charging session
- Billing
- Manage grid
- Operate Charge Point
- Reservation
- Smart Charging

Besides the main functionality of operating a charge point, in more detail the protocol can (also) be used:

- Technically reserving a charge point (i.e. sending a reservation message to a charge point)
- Collecting transaction information for billing purposes

¹⁹ See https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=ocpp

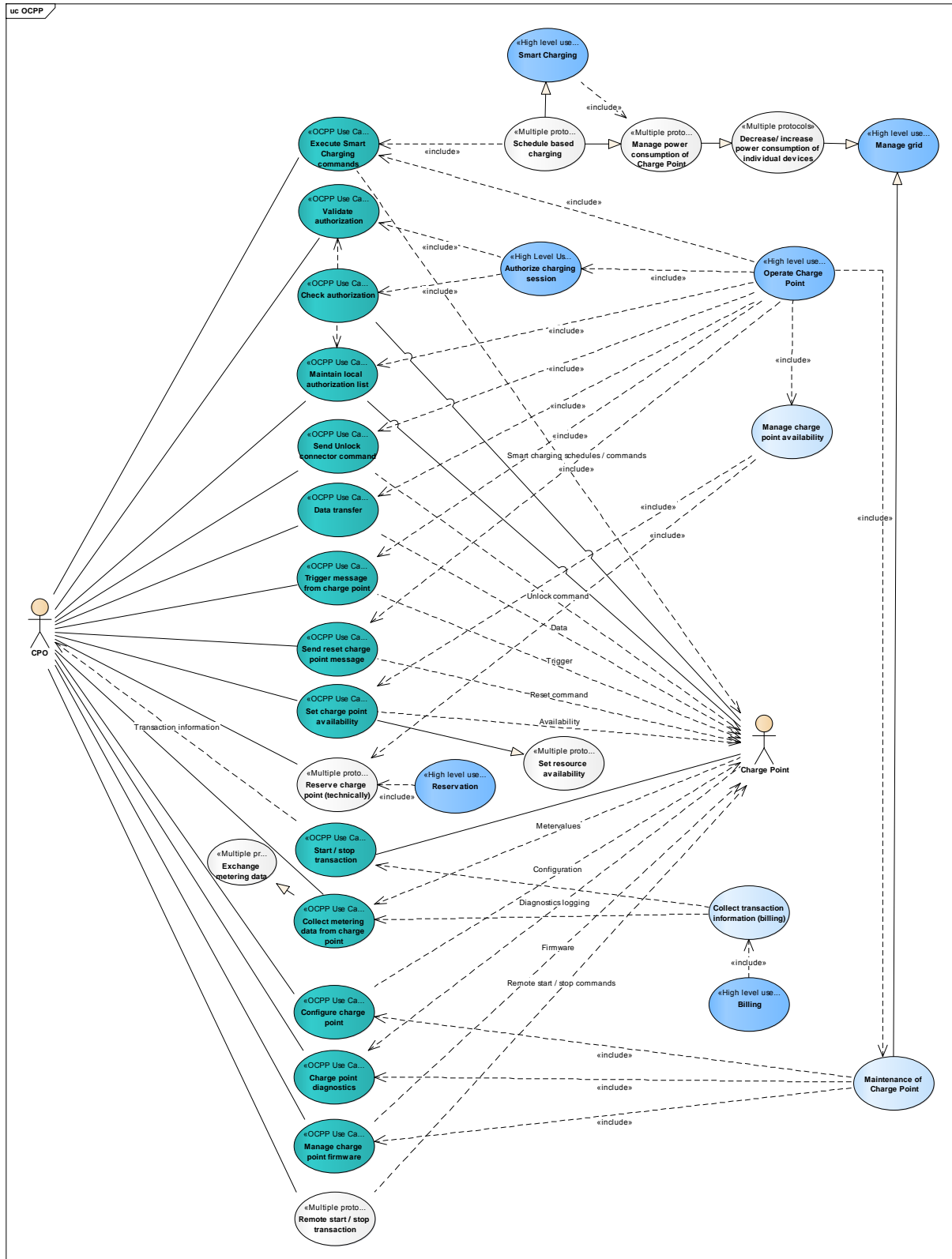


Figure 7: Use case overview of OCPP protocol

Maturity

Many parties have extensively used OCPP over recent years. Version 1.6 is the third “real” release of the protocol – the previous releases of OCPP were 1.2 and 1.5. The protocol has been further developed while it was also being used in practice and has been enhanced both technically as well as functionally over the years. The 1.6 version of OCPP is developed within the Open Charge Alliance. The specification is divided in “profiles”. These profiles include firmware management, smart charging and reservation. A testing tool is offered by the OCA, which can be used to determine whether the implementation of a central system or charge point is correct. This testing tool can play the role of both charge point as well as central system. The technical level of detail of the OCPP specification is high, no separate test specification is available (testing tool specification does specify test scenarios). Currently certification of the protocol is not available. Based on the above, the maturity of the protocol is classified as high.

Interoperability

The OCPP protocol is a strict protocol. It does not only describe messages, but also the related behavior of the central system and charge point is included in the protocol. Furthermore, the protocol also defines scenario’s, such as booting a charge point, and the sequence of messages that is to be used in that scenario. This “strictness” combined with the testing tool to validate implementations, makes the protocol highly interoperable: a correctly implemented central system and a correctly implemented charge point will usually integrate without many problems (if any).

Market adoption

The market adoption of OCPP is high. It has been downloaded over 10.000 times in 91 countries and used on 6 continents. The Open Charge Alliance which was responsible for creating the protocol consists of over 65 parties. Despite the fact that OCPP is not (yet) a formal de jure standard, it is the only non-proprietary standard that supports this key domain for EV charging and has been deployed by many vendors globally. Therefore the market adoption of the protocol is classified as high.

Openness

The OCPP protocol is publically available at no cost from the website of the Open Charge Alliance, without licensing / royalty obligations or usage restriction. It is made available under the Creative Commons Attribution-NoDerivatives 4.0 International Public License (with no other intellectual property assertions). The Open Charge Alliance is not considered an accredited standards organization. Development of successor versions of the protocol were attempted to be carried on through OASIS, which is an accredited standards organization, until the committee was closed by OASIS.

Based on the absence of intellectual property constraints and free public access of the standard, the openness is classified as Medium / high.

5.2.2 IEC 61850-90-8

Introduction

The IEC 61850-90-8 document is not a protocol in itself. It is a technical report which describes an object model for electric mobility. The main purpose of IEC 61850-90-8 is to model E-mobility into IEC61850-7-420 ed. 2, for the integration with other DER types like PV, wind, etc. for a high level of safety and interoperability. This will be withdrawn by IEC when this process is finalized. It models Electric Vehicles as a specific form of Distributed Energy Resource according to the paradigms defined in IEC 61850. The idea is to create a “logical node” model for EV. In this way IEC 61850-90-8 can be used as a protocol: the report itself only describes the object model, but since it defines an object model "in the IEC 61850 way", the properties of the data in this model can be "read" and "set" using the standard messaging protocols for IEC 61850 (i.e. the MMS protocol). Typical use for the standard is getting and setting instantaneous (so no historical) values. In case of remote devices, this boils down to determining the status / state of a device and to determine what kind of device it is (what components, manufacturer of the components etc.). When dynamic properties are defined in the model, such as charging speed, these can also be changed by sending an MMS message to the charge point. Using the protocol in this way, a charge point can be externally controlled.

Use cases supported by IEC 61850-90-8

As discussed in the introduction, IEC 61850-90-8 can be considered as a protocol to control a charge point for both AC as well as (high power) DC charging. However, since it is only described as an object model, no direct use cases can be derived from the specification, except for smart charging. For this reason and because no open charge point implementations of the protocol are known, no use case diagram is added in this study, but only a textual description is given of the “possible” use cases.

The use case *smart charging* is described in the specification as “optimized charging with scheduling from the secondary actor / at EV”. Furthermore, a local reservation scheme is explicitly defined, which makes it suitable for reservation of power (not to be confused with reservations of a charge point for a user). Other possible use cases are managing the grid by adjusting the power (used by charge points) by setting the charging speed. Part of the properties in 61850-90-8 make it possible to do the basics of operating a charge point, but the lack of firmware upgrade functionality etc, makes the protocol in itself not suitable for operating a charge point. To have a complete set, this should be mixed with other standards. Billing is out of scope of the model. Protocol security is not in the 61850-90-8 specification itself, but is described separately in the IEC 62351 specification. This involves security of the protocol itself, not the functionality related to, for example, authorizing a user at a charge point.

Maturity

The model is available as an IEC technical report, however, no existing real life charge point implementation based on the protocol is known. The messages that are sent using 61850 via the MMS protocol can be certified in general, so this also applies to 61850-90-8.

Based on the above, the maturity of the protocol is classified as medium.

Interoperability

The interoperability of the protocol is low. The model is defined in a strict manner, but no relation to behavior is available. This means that no description is available of what behavior is expected when setting a specific parameter.

Market adoption

No existing real life charge point implementation based on the protocol is known, so despite the market adoption of other parts of the 61850 standard, this is classified as low.

Openness

The IEC 61850-90-8 specification is publically available at limited cost from the website of the IEC, containing no IP other than the copyright by IEC. The IEC is considered an accredited standards organization.

The openness is therefore classified as high.

5.2.3 Central system – charge point protocol overlap

Both OCPP and IEC 61850-90-8 can be used to control a charge point. Where OCPP has become a de facto standard, IEC 61850-90-8 could also be used to execute a number of functionalities supported by OCPP. However, due to the fact that OCPP is in use at many companies, IEC 61850-90-8 is not in use and does not define behavior, it is difficult to compare the protocols. However, due to the nature and history of the IEC 61850 protocol, it seems more suitable for direct control of a charge point by a grid operator than for operating a charge point.

The relatively large amount of electric energy that is required for charging EV's can lead to problems in the electricity grid in areas where the grid is not scaled for EV. The two variables that are of concern here are voltage and power. For the variable Voltage maximum and minimum limits are defined for a DSO (usually by law). For power, of course, the physical limits of the electricity grid apply (the maximum amount of power before breakers in substations trip). In the Sustainable Processes report by the Smart Grid Coordination Group [CCE2012], the traffic light concept is used as a framework to consider how interaction should take place within the EV market in different states of the grid. As the word "traffic light" implies, 3 situations are distinguished: a green, yellow and red situation. These situations are schematically presented in Figure 8 (from [CCE2012]). The green area basically means that the market is operating freely, yellow refers to the temporary situation when the DSO actively engages in the market to keep the grid / system from becoming unstable. Red refers to the temporary situation when the DSO needs to take control of the market in specific areas due to grid constraints.

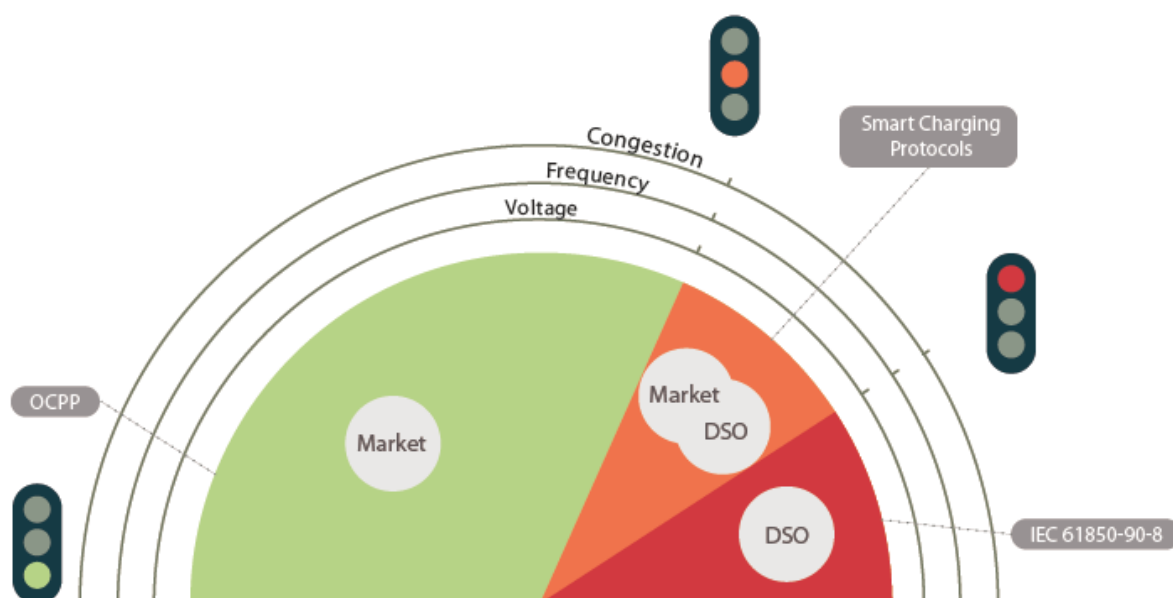


Figure 8: Traffic light concept (from [CCE2012])

In the green and yellow situation, OCPP can operate as normal. In case of a yellow situation the DSO could be involved in the market using one of the smart charging protocols (see paragraphs 5.1.1 to 5.1.4). In this scenario, the OCPP protocol can be used for setting charging limits or to stop charging.

However, in the red situation, some DSO's want to take control by directly setting limits on the charge point. This seems the most appropriate application of the IEC 61850-90-8 protocol, since the IEC 61850 protocol in general is the conventional way for DSO's to take control of remote devices in the network.

5.3 Roaming

IN THE TELECOM INDUSTRY “ROAMING” IS THE ABILITY OF USERS TO MAKE USE OF THEIR PHONES/SUBSCRIPTIONS BEYOND THE LIMITS OF THE NETWORK OF THEIR PROVIDER OF CHOICE. IT ALSO COVERS THE AGREEMENTS BETWEEN PROVIDERS TO MAKE THIS POSSIBLE. IN THE EV DOMAIN ROAMING IS VERY SIMILAR: THIS IS WHAT ALLOWS EV DRIVERS CHARGE THEIR EV AT CHARGING STATIONS THAT ARE NOT PART OF THE CHARGING NETWORK OF THEIR CPO USING THE SAME IDENTIFICATION

5.3.1 Open Clearing House Protocol (OCHP)

Introduction

The Open Clearing House Protocol (OCHP) is a protocol which is meant for exchanging authorization data, charging transaction and charge point information data for roaming. The protocol consists of 2 parts:

1. A part that is specifically for communication between market parties and an EV clearing house
2. A part that is for peer to peer communication between market parties, this is called OCHPdirect

The protocol is currently used with the e-clearing.net clearing house platform, which is operated by smartlab Innovationsgesellschaft mbH and owned by both smartlab and ElaadNL on an equal shares basis (non-profit). The version under consideration is 1.4.

Use cases supported by OCHP

In Figure 9 and (see next pages) the use cases that are supported by OCHP are visualized. Due to the size of the diagram, separate diagrams for OCHP and for OCHPdirect are included. The high-level use cases as listed in paragraph 4.1.4 that are supported by this protocol are all aimed at roaming:

- Authorizing charging sessions
- Billing
- Providing charge point information
- Reservation
- Roaming
- Smart Charging (only in OCHPdirect, in a basic / lean form)

In more detail, it also includes:

- Remote Control of Charge Point (only in OCHPdirect). This includes setting limits, but this is not targeted at dynamic Smart Charging (yet).
- Providing tariff information
- Providing Charge Detail Records for billing
- Providing charging session information (only in OCHPdirect)

Maturity

Over the last 3 years, every year a new version of the protocol was released (most recently OCHP 1.4 & OCHPdirect 0.2 in Q4/2016). Since the protocol has been in active use for those years by a number of parties, practical experience has been included in the development. The protocol is maintained within e-clearing.net. Currently, certification is not possible and no dedicated / specific testing tool is available. However, before a party gets access to the productive environment of the clearing house, first a complete implementation test is executed (including correctness checks), which can be considered a “quasi-certification”.

The maturity of the protocol is qualified as high.

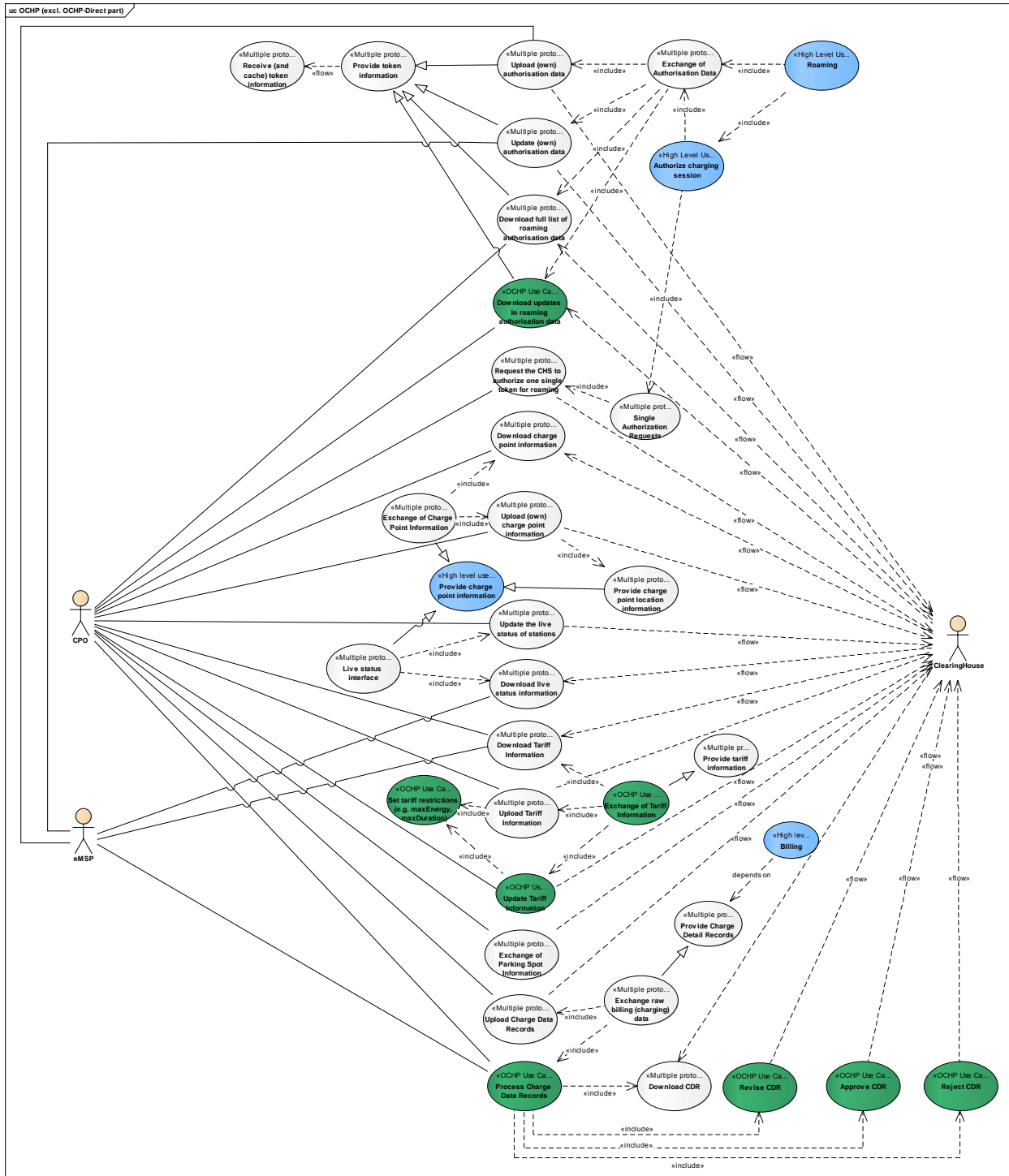


Figure 9: Use case overview of OCHP protocol (excl. OCHPdirect)²⁰

²⁰ OCHP also identifies the roles of POI consumer and Parking Spot Operator (to provide parking spot live data). In this study these roles are gathered under the roles of EMSP and CPO respectively.

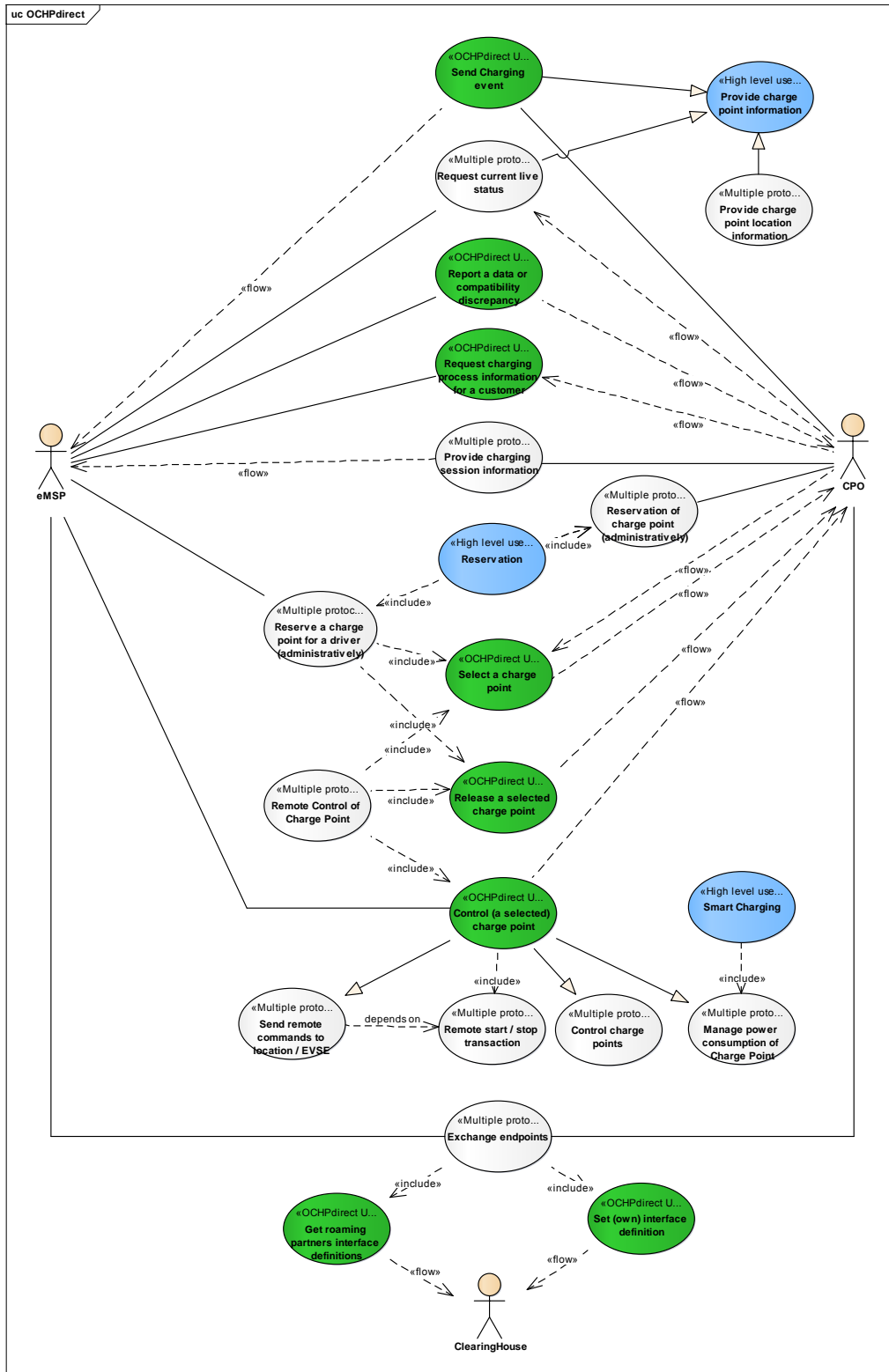


Figure 10: Use case overview of OCHPdirect protocol

Interoperability

The OCHP is a strict protocol. It does not only describe messages, but also the related behavior of the CPO's and the clearing house. Furthermore, the more elaborate use cases are explained in more detail. This "strictness" makes the protocol highly interoperable: a correctly implemented system using OCHP and a correctly implemented clearing house will usually integrate without many problems (if any). For OCHPdirect a similar strictness is applicable.

Market adoption

Currently 24 market parties in Europe are using the platform, including the OCHP, which covers a number of countries within Europe including Germany, France, Austria, Netherlands, Belgium and England. Within this region the market adoption can be classified as high. However, when looking at the market adoption over the world, the overall market adoption is classified as medium / high.

Openness

The OCHP is publically available at no cost from the website of e-clearing.net. It is made available under the MIT license. Stakeholders and users are encouraged to take an active role in the further development of the protocol and the platform, with yearly workshops to collect feedback and requirements. E-clearing.net is not considered an accredited standards organization. There is a public repository on Github for development, issue tracking and collaboration.

The openness is therefore classified as medium.

5.3.2 Open Charge Point Interface protocol (OCPI 2.1)

Introduction

The Open Charge Point Interface protocol is designed for exchanging information about charge points. The protocol is for exchanging information between the market roles of Charge Point Operator and e-Mobility Service Provider. These roles are not separated in all markets. In some countries or regions these roles are filled in by one party.

The OCPI protocol originates from the Dutch EV market, where, starting in 2009, a number of CPOs and EMSPs (collaborating under the name eViolin) together with ElaadNL, created a first version of a protocol for exchanging information concerning charge points. Eventually in 2014 this resulted in the development of OCPI. Version 2.1 was published in 2016. The Netherlands Knowledge Platform for Charging Infrastructure (NKL) facilitates and coordinates this project to guarantee progress and ensure development and results.

Use cases supported by OCPI 2.1

In Figure 11 (see next page) the use cases that are supported by OCPI are visualized. The high-level use cases as listed in paragraph 4.1.4 that are supported by this protocol are aimed at roaming:

- Authorizing charging sessions
- Billing
- Providing charge point information²¹
- Reservation
- Roaming
- Handle registrations

In more detail, it includes:

- Providing both session information as well as location information.
- Sending remote commands among which reservation commands.
- Providing Charge Detail Records for billing purposes
- Providing tariff information
- Authorizing charging sessions by exchanging tokens

Maturity

The 2.1 version currently has a low market adoption, so not much experience with the protocol is available. The level of detail of the specification is high, no test specification is available. A concrete plan for a new version / release from "NKL Nederland", the organization that is further developing the protocol, is available. Currently certification is not possible. No testing tool is available. The number of parties that is currently implementing the protocol is < 10.

Based on the above, the maturity of the protocol is classified as low / unknown.

Interoperability

The OCPI protocol is a strict protocol, which makes the interoperability high. It not only describe the protocol messages in much detail, but also the transport layer including error codes etc. are described. Since the protocol is peer-to-peer and primarily for exchanging information (and some commands), not much protocol related behavior is applicable.

Based on the above, the interoperability of the protocol is classified as high.

²¹ Actually, the protocol can be used to provide information about "EVSE's" and not about "charge points". However, for being able to compare the protocols, this term is used. In detail: EVSE is the logical unit in a charge point that supplies electric energy via a Connector for charging. An EVSE can have one or multiple Connectors (single physical outlets).

Market adoption

Due to the fact that OCPI is an emerging protocol, without a large driving organization, no detailed information about the users of the protocol are available. Based on the market adoption in the Netherlands, where the protocol emerged but the 2.1 version is not yet implemented at the important market parties, the current market adoption is classified as low.

Openness

The OCPI version 2.1 protocol is publically available at no cost from the website of NKL Nederland. It is made available under the Creative Commons Attribution-NoDerivatives 4.0 International Public License. NKL Nederland is not considered an accredited standards organization. Development takes place via an open GitHub page, anyone can contribute.

The openness is therefore classified as high.

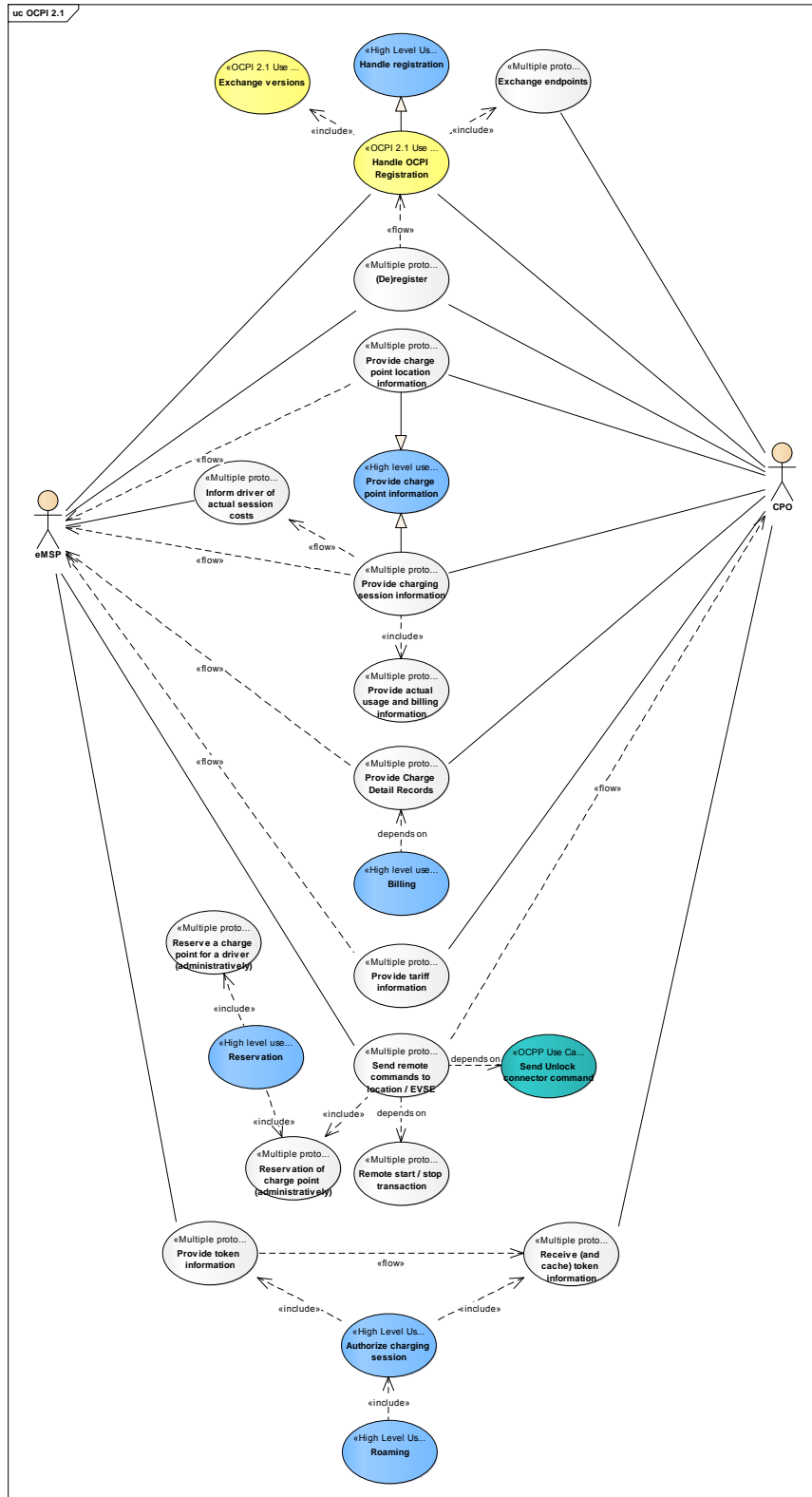


Figure 11: Use case overview of OCPI 2.1 protocol

5.3.3 Open InterCharge Protocol (OICP)

Introduction

The Open InterCharge Protocol (OICP) is a roaming protocol created by Hubeject in 2013, which can be used to communicate with the Hubeject B2B Service Platform. This platform enables exchanging roaming messages between an EMSP and a CPO. Since 2016 the protocol consists of 2 parts that together create the protocol: a separate part for the EMSP and a separate part for the CPO. The version under consideration is 2.1.

Use cases supported by OICP

In Figure 12 (see next page) the use cases that are supported by OICP are visualized. The high-level use cases as listed in paragraph 4.1.4 that are supported by this protocol are aimed at roaming:

- Authorizing charging sessions
- Billing
- Providing charge point information
- Reservation
- Roaming

In more detail, it includes:

- Providing Charge Detail Records for billing purposes
- Providing both session information as well as location information
- Reserving charge points
- Sending remote start / stop commands

Maturity

Over the last 2 years, multiple new versions of the protocol have been released. Hubeject actively manages the API Releases. One release is supported for a maximum of 2 years. Which leads to two active versions at once and a higher reliability for implementation partners. The protocol is in active use for those years by a number of parties. According to the specification, it is *“the most widely implemented communication standard between European EMSP and CPO systems”*. No testing tool is available. Certification can be done, which is called the “Check eRoaming system“. This is a certification of Hubeject-compatibility for both charge points as well as customer management systems. Certification is done by means of end-to-end testing (audit). According to the specification, a new version of the protocol is released every year during spring / summer and will become productive October 1st, a protocol version is supported for 2 years.

Based on the above, the maturity of the protocol is classified as high.

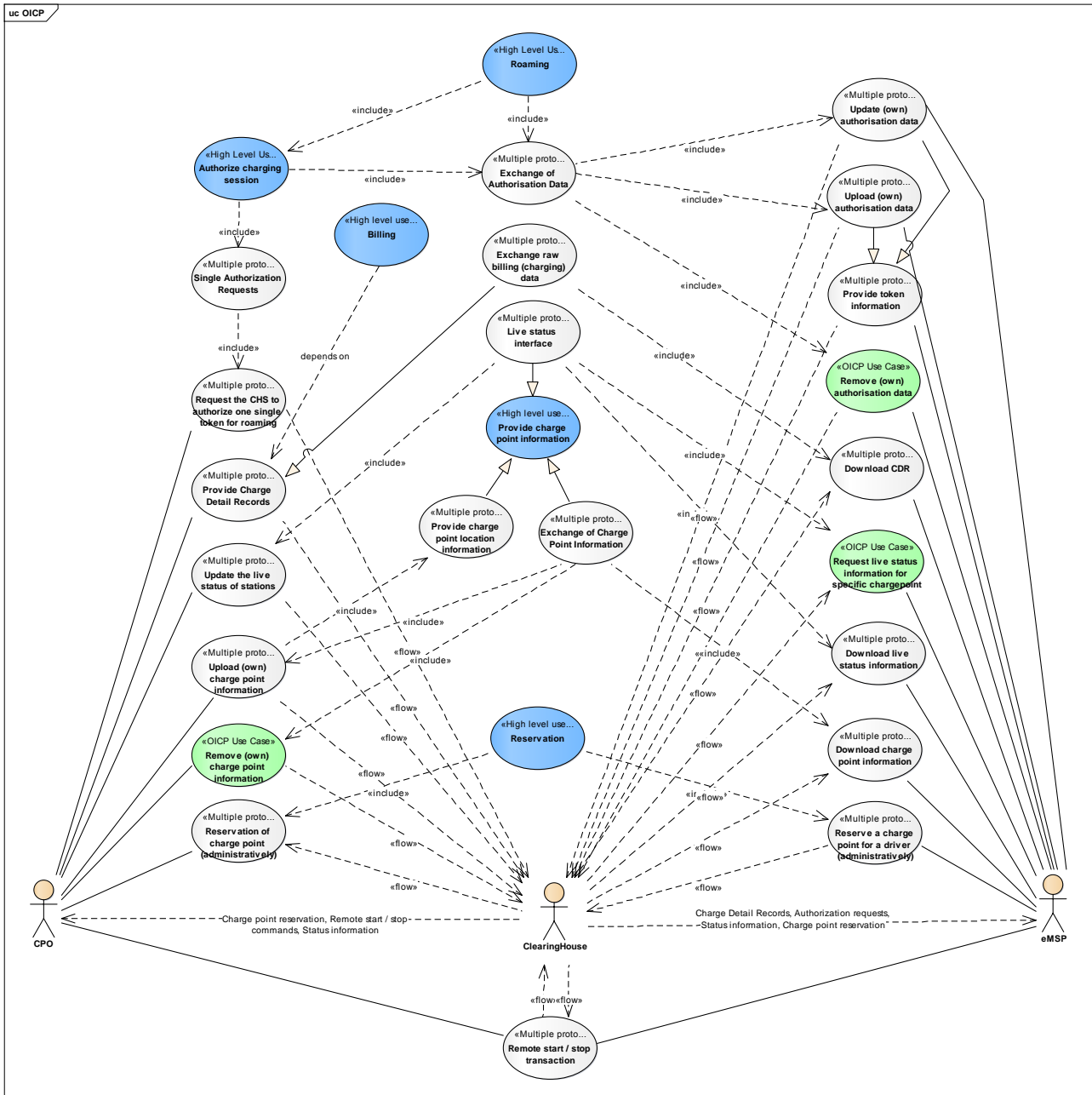


Figure 12: Use case overview of OICP 2.1 protocol

Interoperability

The OICP protocol is a strict protocol. It does not only describe messages, but also the related behavior of the clearing house and the EMSP end CPO roles are included in the protocol. This “strictness” makes the protocol highly interoperable: a correctly implemented system using OICP and a correctly implemented clearing house will usually integrate without many problems (if any).

Market adoption

According to the specification, it is “*the most widely implemented communication standard between European EMSP and CPO systems*”. It is not the only clearing house in Europe (see also chapter 5.3.1 and 5.3.4), but it is used by the largest number of B2B customers in Europe (currently more than 240 partners). The market adaption is therefore classified as high.

Openness

The OICP protocol is publically available at no cost from the website of Hsubject, containing no IP except for copyright by Hsubject, which is not considered an accredited standards organization.

The openness is therefore classified as medium.

5.3.4 eMobility Inter-Operation Protocol(eMIP)

Introduction

The eMobility Interoperation Protocol (eMIP) is provided by the GIREVE organization. The main objective of GIREVE is: “*open access to vehicle charging stations*”. The eMIP protocol targets the following goals (from the specification):

- *Enabling roaming of charging services by providing a charge authorisation and a data clearing house API.*
- *Providing access to a comprehensive charging point database.*
- *Providing smart charging features*

GIREVE is founded by EDF, Renault, ERDF, CNR and Caisse des Dépôts. The initiative started in 2012, aimed at roaming. In 2014 a cooperation with the Hsubject platform was announced.

Use cases supported by eMIP

In (see next page) the use cases that are supported by eMIP are visualized. The high-level use cases as listed in paragraph 4.1.4 that are supported by this protocol are aimed at roaming:

- Authorizing charging sessions²²
- Billing
- Providing charge point information
- Roaming

²² In more detail: real-time local + remote authorization and whitelists exchanges.

- Smart charging

In more detail, it includes:

- Providing Charge Detail Records for billing purposes²³
- Providing charge point information incl. tariff and parking spot information (static and dynamic)²³
- Smart charging functionality (→ open to any OEM, currently connected to one OEM)
- Retrieving list of EVSE's located in a given area and fulfilling a set of criteria (i.e. “search functionality”)
- Sending event reports and remote commands (emergencystop, stop, suspend and restart)

Maturity

The current version of the protocol is 0.7.4. No information about other versions is available.

Currently certification by Gireve is possible and is required for a connection to the Gireve platform. No specific / dedicated testing tool is available, however SOAPUI mock services are available for both CPO and EMSP related services. Furthermore, testing environments are available for partners that intend to connect to the Gireve platform.

Based on the above, the maturity is classified as high.

Interoperability

The eMIP protocol does not only describe messages, but also the related behavior of the clearing house and the EMSP and CPO roles are included in the protocol. Approximately 70%-80% of the fields in the protocol are mandatory except for the charge point search functionality. A correctly implemented system using eMIP and a correctly implemented clearing house are therefore expected to integrate without many problems. eMIP is compatible with eMI3 / ISO way of identifying business objects.

Therefore the interoperability is classified as high.

Market adoption

Gireve is not the only platform with clearing house functionality in Europe (see also chapter 5.3.1 and 5.3.3). The main market for Gireve is France. The EV charging infrastructure deployment is in progress in France and the number of EVSE connected (to CPO's connected) to Gireve follows this ramp up. Gireve is also (directly) connected to European CPO's for POI information. No exact information on the number of involved parties / participants is available, but this number appears to be relatively small when compared to the other roaming protocols.

The market adaption is therefore classified as medium.

²³ Both push / pull mechanism

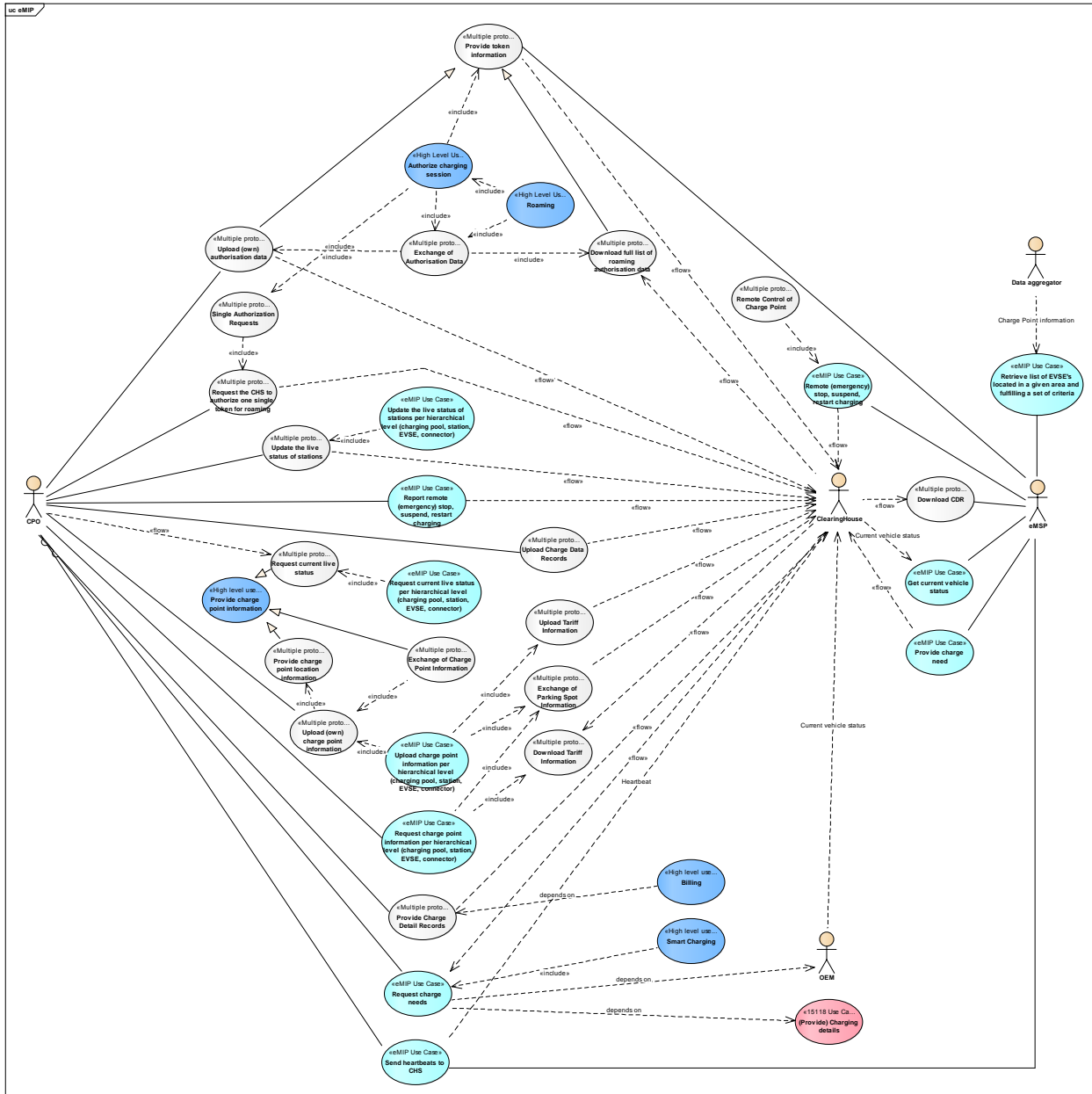


Figure 13: Use case overview of eMIP protocol

Openness

The eMIP protocol is not publicly available from the website of Gireve. According to the specification and license agreement, the protocol is the “exclusive property of GIREVE in accordance with the provisions of the Code of the intellectual property”. Although the eMIP protocol is an asset of Gireve (IP), a license is granted to any operator (that demands) for free. Based on this license, the operator can use the eMIP protocol, to do “what it wants” and non-exclusively to access the Gireve platform.

Gireve is not considered an accredited standards organization.

Based on the above, the openness is classified as low / medium.

5.3.5 Roaming protocols

The roaming protocols OCPI, OICP 2.1, eMIP and OCHP have a quite some overlap. When looking at a high level, the only differences are that eMIP and OCHP support smart charging and that OCPI also supports handling registrations. This last functionality is, as will be explained below, logically.

Table 2: High level view on EV roaming protocols

	OCHP	OCPI 2.1	OICP	eMIP
PROTOCOL	ROAMING			
Authorize charging session	•	•	•	•
Billing	•	•	•	•
EV Charging				
Handle registration		•		
Manage grid				
Operate Charge Point				
Provide charge point information	•	•	•	•
Reservation	•	•	•	
Roaming	•	•	•	•
Smart Charging	•			•

However, when looking in more detail, the following differences exist:

- The main difference is the **different communication setup** between the protocol users: the OCHP, eMIP and OICP protocols are used to communicate *via a clearing house*. The OCPI 2.1 protocol and the OCHPdirect protocol are used directly between parties as a peer-to-peer protocol. The main advantage of a clearing house is that only one connection is to be established to the clearing house and not a connection per partner. In a peer-to-peer setup, n partners means $\frac{n(n-1)}{2}$ connections (for example, 10 partners, means $10 \times 9 / 2 = 45$ connections). The main advantage of a peer-to-peer setup means that it has no dependency of 1 platform (“single point of failure”). Its peer-to-peer setup also explains the fact that OCPI has possibilities for registrations.
- Another difference is that the communication between OCHP parties is **asynchronous** (parties can upload / download files), OCPI is a **synchronous** protocol: a request is directly answered by a synchronous response. In the Hubject and GIREVE platform for which OICP and eMIP are used, both patterns exist for different messages.
- When looking in more detail, not all **functionalities** overlap. Some notable differences are the following:
 - OCHP has separate steps (approve / reject / revise) for exchanging CDRs
 - OCHP and OCPI can be used for exchanging tariff information, OCHP supports setting tariff restrictions.
 - OCHP and eMIP explicitly support exchanging parking spot information.
 - OCPI supports exchanging version information (to support multiple protocol versions). Again the need for such a feature is larger due to the peer-to-peer setup.

- eMIP, OCPI and OCHP (Direct) support both live status information as well as session information. OICP only supports status info which includes live status information (slightly different implementation).
- When including the **platforms** that are used in combination with the protocols, OCPI (no CHS) and OCHP offer the possibility to choose with whom roaming will take place, instead of roaming with all platform users.
- The GIREVE platform as a separate **charge point repository**.
- eMIP is the only roaming protocol that has **no reservation** functionality (yet), but does have **support for smart charging**. Part of the smart charging process as it is defined by the protocol depends on the current EV status. According the specification, this is requested at an **OEM** of the EV (Renault is one of the founders). The older version of the OCPI protocol (0.4) also included smart charging, but this functionality was removed in version 2.1 (and is on the roadmap for a newer version again).
- OCHPdirect supports a primitive form of smart charging.

The main differences are visualized in Figure 14.

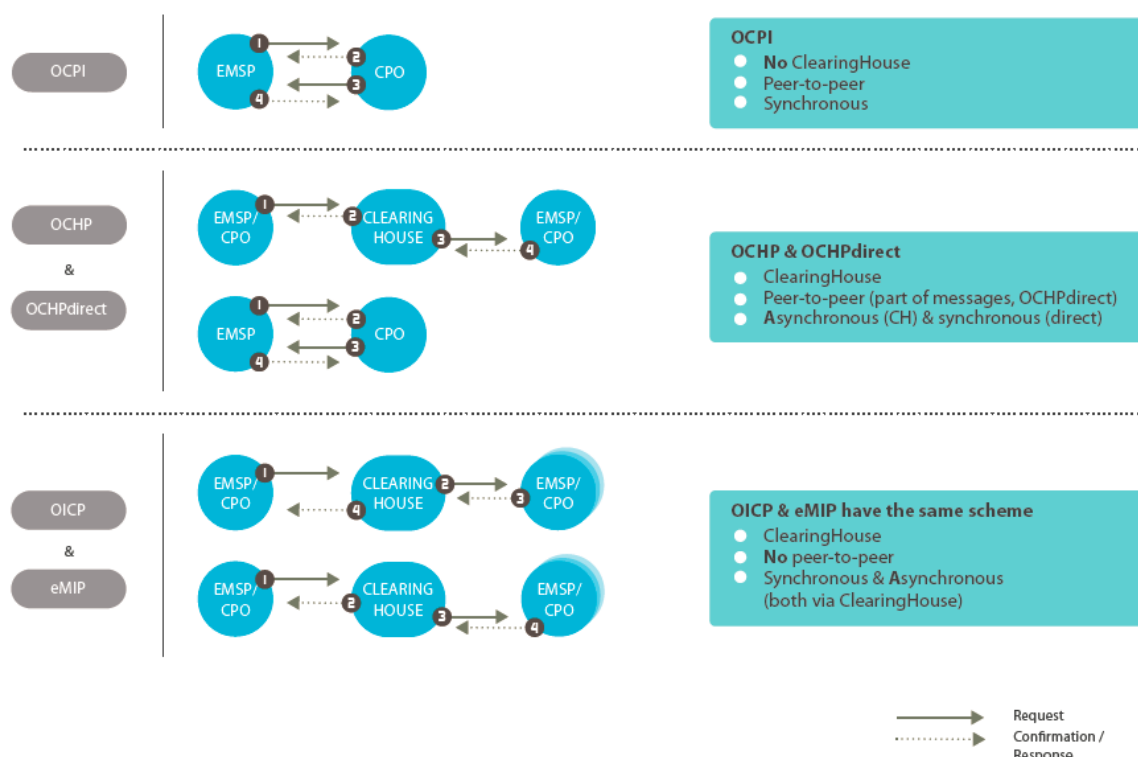


Figure 14: Schematic comparison of roaming protocols

Currently a pilot is executed to couple the different platforms (for POI information). The objective of this pilot is to show that it is possible to couple the platforms. The PanEuropean eRoaming Initiative between Hubeject, Gireve and e-clearing.net aims at providing a first pilot implementation of “interroaming” by Q3/2017 covering the basic POI, authorization and CDR exchange services across all three platforms.

5.4 EV – Charge Point

5.4.1 IEC 61851-1

Introduction

The IEC 61851-1 edition 2 is a standard published in 2010, which concerns basic charging. It is an official IEC standard, created by the “*IEC technical committee 69 (TC69): Electric road vehicles and electric industrial trucks*”. The 2010 edition replaces the first edition from 2001, Edition 3 is under development.

Use cases supported by IEC 61851-1

The IEC 61851-1 describes 4 modes for EV charging. In short, these modes refer to:

- Mode 1: basic AC charging to a maximum of 16A / 1x250V / 3x480V.
- Mode 2: basic AC charging to a maximum of 32A / 1x250V / 3x480V including some additional features, such as standardized socket-outlets, power and protective earth conductors together with a control pilot function and system of personnel protection against electric shock.
- Mode 3: AC charging with basic signaling (Pilot control function) where the control pilot function extends to control equipment in the charge point, gaining the ability to activate / deactivate the power flow and set charging rate limits.
- Mode 4: charging using an off-board charger and high level communication (Powerline or CAN).

When looking at the high level use cases as listed in paragraph 4.1.4, this boils down to only EV charging. Besides this, when smart charging an EV, mode 3 charging is often used to set / change upper limits on charging speed during charging. In most current setups this is used for smart charging based on external control signals. So for completeness, the high level use case smart charging is also considered applicable, although this is basically only refers to adjusting charging speed during charging.

Maturity

The IEC 61851-1 standard from 2010 is the second edition of the protocol. It is currently *the* standard for EV charging in Europe. It can be tested and certified at different certification / test laboratories.

Based on the above, the maturity of the protocol is classified as high.

Interoperability

The IEC 61851-1 standard describes EV charging in detail. Based on the experience with the protocol, the interoperability of the protocol is classified as high.

Market adoption

IEC 61851-1 is currently *the* standard for EV charging in Europe. This means that many thousands of charge points and every EV supports the standard. Based on this, the market adoption of the protocol is classified as high.

Openness

The IEC 61851-1 standard is publically available at limited costs from the website IEC, containing no IP other than the copyright by IEC on using the standard. The IEC is considered an accredited standards organization.

The openness is therefore classified as high.

5.4.2 ISO / IEC 15118

Introduction

The ISO / IEC 15118 protocol specifies a communication standard between a charge point and an EV. The ISO/IEC Joint Working Group 15118 for the Vehicle-to-Grid Communication Interface (V2G CI) was founded in 2009. In this specification a more advanced form of communication is described, also referred to as High Level Communication (HLC). This enables EV's to communication information (for example how full the battery is) to a charge point, without intervention of the EV user (autonomously) in a more advanced way.

The ISO / IEC 15118 standard currently consists of several parts, which describe the protocol on different levels of the OSI reference model (ISO/IEC 7498-).

- Part 1: Describes the use cases and basic definitions²⁴
- Part 2: Describes the network and application protocol requirements²⁴
- Part 3: Describes the physical layer and data link layer.
- Part 4: Describes Network and application protocol conformance test
- Part 5: Describes physical and data link layer conformance tests
- Part 8: Physical layer and data link layer requirements for wireless communication

Use cases supported by ISO / IEC 15118

In Figure 15 (see next page) the use cases that are supported by ISO / IEC 15118 are visualized. The high-level use cases as listed in paragraph 4.1.4 that are supported by this protocol are aimed at EV charging:

- Authorizing charging sessions
- Smart Charging

²⁴ second edition currently under development

- EV charging
- Reservation

In more detail, this includes:

- Schedule based charging, with schedules from both external sources as well as the EV.
- Certificate handling.
- Value added services, only one of these could be reservation.

Maturity

The ISO 15118 protocol is not in use in many charge points and EV's yet, so no extensive experience with the protocol is available. The protocol is defined in detail on the different levels, in many details. All currently available EVs that are equipped with the Combined Charging System (CCS) have the ISO 15118 or DIN SPEC 70121 implemented in their controllers²⁵. Furthermore, according to a directive of the European Commission each newly installed DC fast charger in Europe has to be equipped with CCS and hence with ISO 15118 / DIN SPEC 70121. Based on the above, the maturity of the protocol is classified as medium.

The conformance tests for the protocol are described in part 4 and 5 of the protocol. No official testing and certification is available, although conformance testing is executed by some research institutes.

Interoperability

The protocol is defined in detail on the different ISO levels. It clearly describes both the use cases as well as the technical details of the protocol. This combination makes the interoperability high (potentially).

Market adoption

The market adoption of the ISO / IEC 15118 standard is currently still low, but is expected to grow in the coming years. No official implementations in EV's are currently available, although many car manufacturers are "working on it". Some charge point manufacturers have implementations and open source implementations are available (see also the section about maturity).

Openness

The ISO/ IEC 15118 protocol is available at limited cost from the website of ISO, containing no IP other than the copyright by ISO. ISO and IEC are both considered accredited standards organizations.

The openness is therefore classified as high.

²⁵ DIN SPEC 70121 is a pre-standard based on the ISO 15118 with only a few differences in the message set.

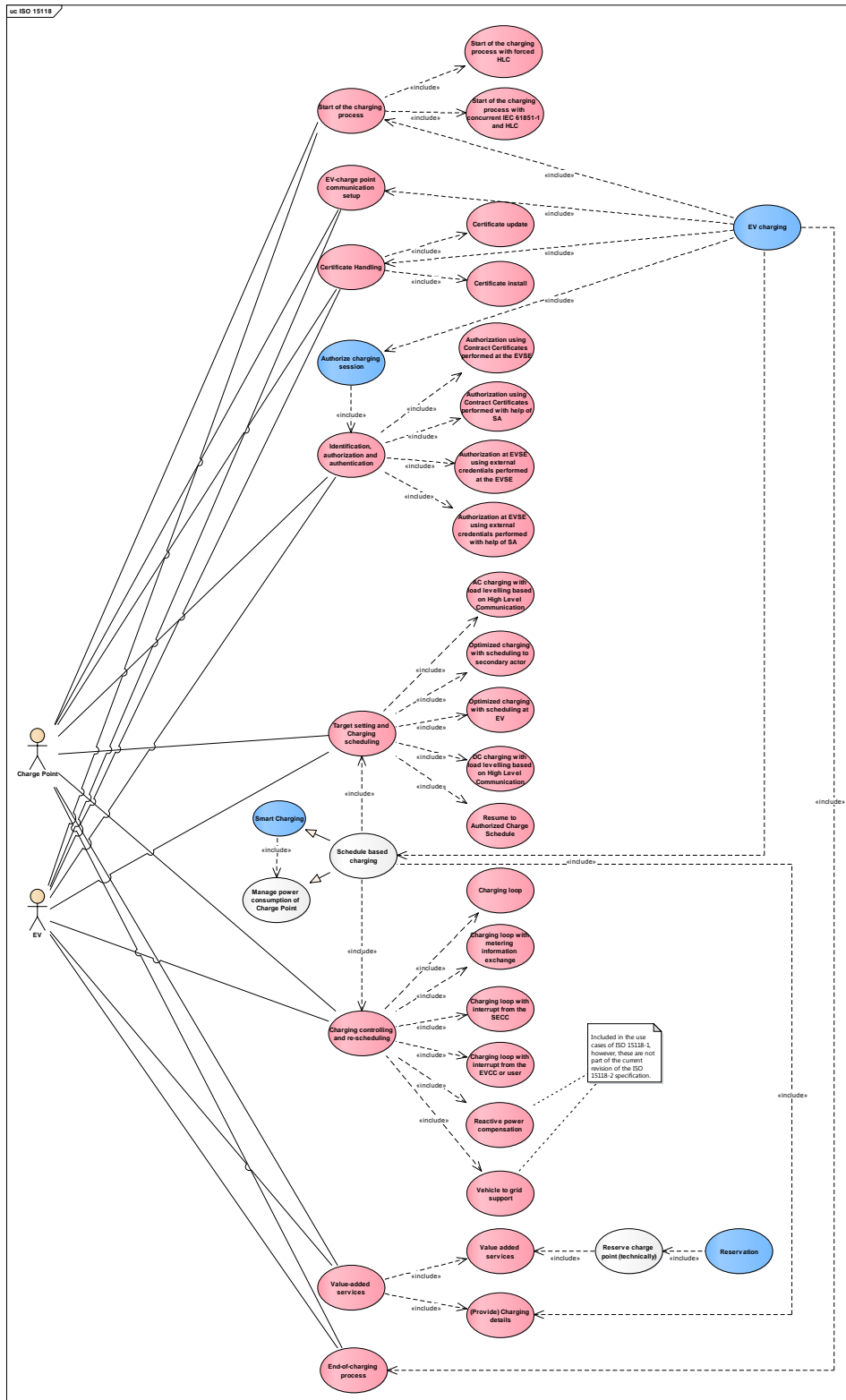


Figure 15: Use case overview of ISO / IEC 15118 protocol

5.4.3 EV – Charge Point protocols overlap

Basic communication between charge point and EV for charging can be done using the IEC 61851-1 protocol (which is even mandatory according to regulation). This standard is only targeted at EV charging. The ISO / IEC 15118 can be considered the next step in charge point – EV communication: using the 15118 protocol, it is not necessary anymore to communicate high level information either by the EV user (via an app) or the EV in non-standard way (which means not interoperable); this is part of the protocol. Although both protocols can be used in a smart charging chain, the ISO / IEC 15118 protocol is far more advanced, since it supports “High Level Communication”.

However, when looking at market adoption, the 61851-1 standard has a very high market adoption whereas no implementations of the ISO / IEC 15118 protocol are known (other than pilot projects)²⁶.

²⁶ More input from OEMs concerning future plans is needed here to make a better comparison.

6. PROTOCOL DISCUSSION

6.1 Overview

In Figure 16 the different roles and protocols in scope for this study are visualized. Some of the protocols are easy to position, since those are made for a specific purpose. These are drawn with solid lined. Other protocols, such as IEEE 2030.5 and OpenADR are more broad / generic protocols, which makes them suitable for use at multiple places in the EV market chain. This is visualized with dotted lines.

In the discussion in this chapter, the assumption is that some kind of control of a charge point is possible. In the first part of this chapter we focus primarily on charging on public ground, not on in house charging “behind” the electricity meter. This architecture is discussed briefly in paragraph 6.6. In this architecture a lot of functionalities from the protocols described in this study might not be required, for example roaming and authentication.

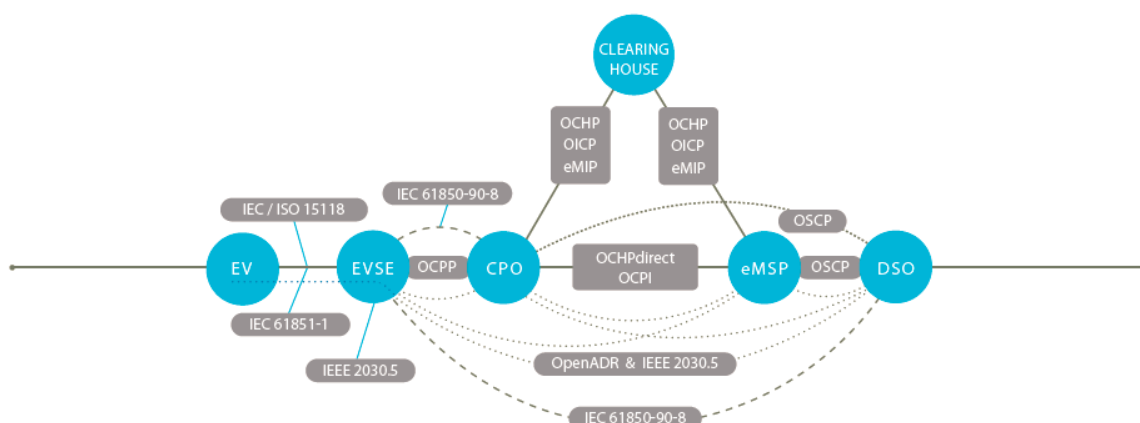


Figure 16: overview of protocols and market roles

An important note to be made is that the reader should realize that these are roles, not companies. The same role might be filled by many different companies (competitive market). At the same time, some of the roles might be filled in by the same company. Reality will be more complex or perhaps less obvious than the model suggests.

In Figure 17, this complexity is visualized and the role of OEM is also added to the figure. Currently no open standards / protocols are available to communicate with the OEM within the EV market chain. The rightmost role of the DSO role is replaced by the combination of DSO, TSO (Transmission System Operator) and BRP (Balance Responsible Party).

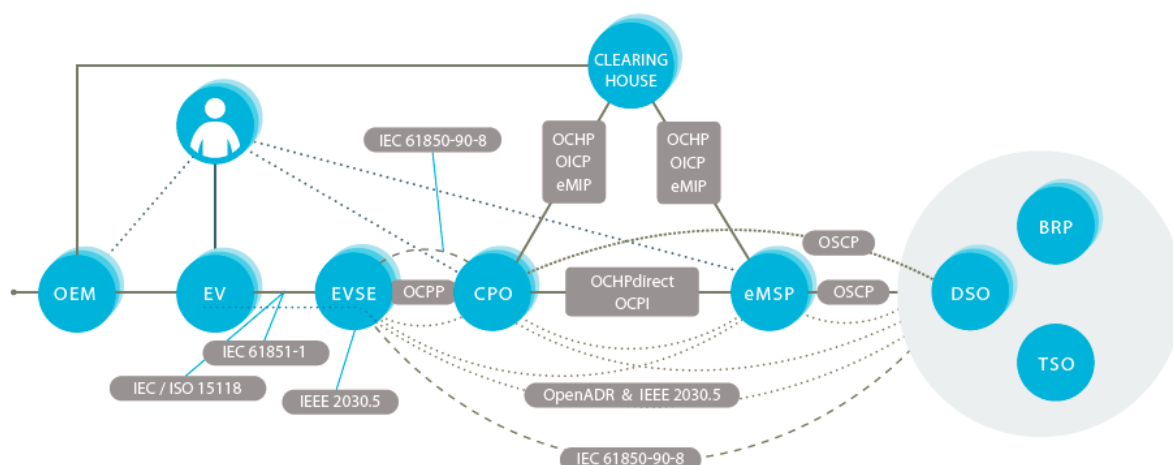


Figure 17: More complex view of protocols

Another addition to the figure is the EV user. There are a lot of ways available for communicating with the EV driver, such as through the EV (ISO / IEC 15118), apps, websites, helpdesks, manuals, on-site way of working stickers etc. but currently none of those is standardized. This also depends on the existing role model / market model in the specific country, region or continent. However, at many locations no communication to the user is available, other than the beeps (and displays) on charge points.

Furthermore, the party that communicates with an EV user is not necessarily the same in every location. EV users may sometimes even be “forced” to use different apps (e.g. a generic app for finding charge points, a CPO or EMSP app for starting EV charging).

6.2 EMSP – CPO communication

Currently the communication between the EMSP and CPO roles has 2 types: point-to-point communication and communication via clearing houses (see Figure 18). Within liberalized energy markets, clearing houses are a common solution, once a market is more mature. When many parties participate in a market, point-to-point communication usually becomes difficult to control and a step towards a hub / clearing house is made. This is now happening in the EV market, mostly on national and / or regional level. A hub provides an efficient means of cooperation. The development speed depends on the cooperative nature of the parties involved and governmental influence. In the situation that parties are intrinsically motivated, the mutual connection to a hub is smoother with less hurdles. Besides the ICT-system also the (compulsory) business rules involved in connecting to a hub (and other parties connected to this hub) play an important role in the organic growth of parties connected to a hub.

A centralized vs decentralized solution can also be viewed as a “wave”. Current developments in the Internet of Things (IoT) and blockchain tend to decentralized solutions again.

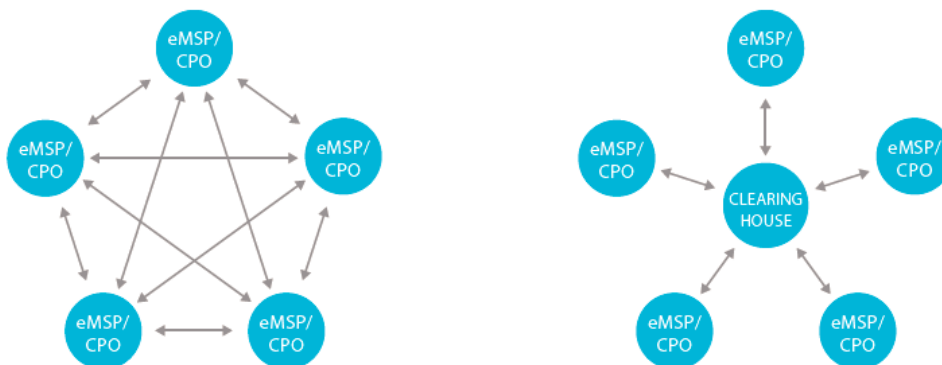


Figure 18: Point-to-point setup vs. clearing house setup

The main focus of the communication between EMSP and CPO is roaming, functionality for smart charging is only available in the eMIP protocol and OCHPdirect as already indicated in chapter 5.3.5. This functionality was available in the old version of the point-to-point protocol OCPI, but was removed in the 2.0 version (and is planned to be reintroduced in a newer version again). Therefore, the next step for the roaming protocols seems to be the addition / extension of smart charging functionality. One may wonder whether the intermediate step via a point-to-point protocol is necessary or that the focus should directly be on the clearing house type of communication. One drawback of adding smart charging to the clearing houses, is that currently multiple clearing houses exist. These should either communicate with each other or market parties should be able to connect to multiple platforms (see Figure 19). Having multiple connections is of course not the aim of using a clearing house, but it would at least limit the amount of connections²⁷.

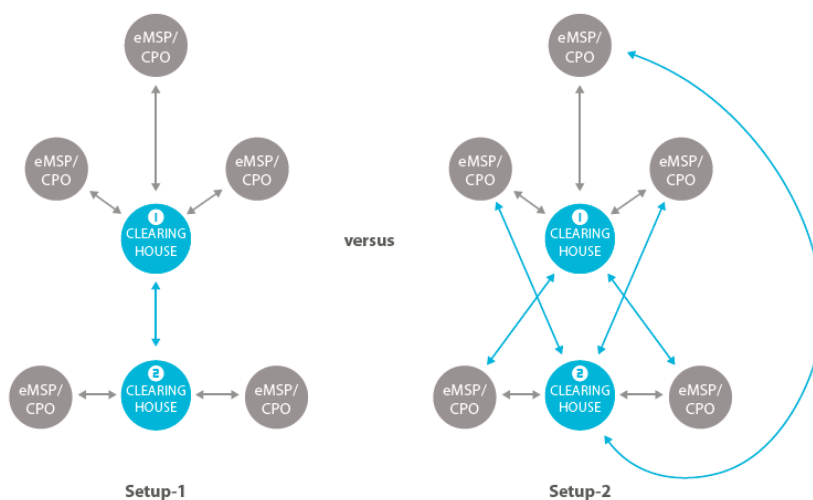


Figure 19: Multiple clearing houses setup

²⁷ Currently an initiative is under development to use the OCPI protocol for communication to the eclearing.net platform.

Using a point-to-point OCPI solution makes it easy to enable roaming with only a small selection of parties. Extending it with smart charging only seems a solution for the short term. When connections to OEM's are considered necessary for smart charging (see 6.4 for more details on the relation between OEM's and smart charging), this would also imply that all OEM's should provide open API's for market parties. This would make the number of connections between parties within the EV market even larger.

6.3 EV charging

In this study EV charging refers to charging an EV at a charge point. After some form of identification and authorization, the EV gets charged without any external imposed limits / schedules (sometimes called “dumb charging”). If the EV user is not a direct customer of the party that validates the authorization credentials (usually a CPO), some form checking the authorization at other parties is required. This process, usually referred to as “roaming”, is also considered part of EV charging in this study. Currently the maturity in the EV domain has evolved to a level that charging without roaming is not considered as a serious option anymore. Charging without roaming (“ad-hoc charging”) is therefore not discussed in this document.

A commonly used EV charging setup in (continental) Europe, is visualized in Figure 20. No input from the DSO is taken into account, so only IEC 61851-1, OCPP and one of the roaming protocols is used.

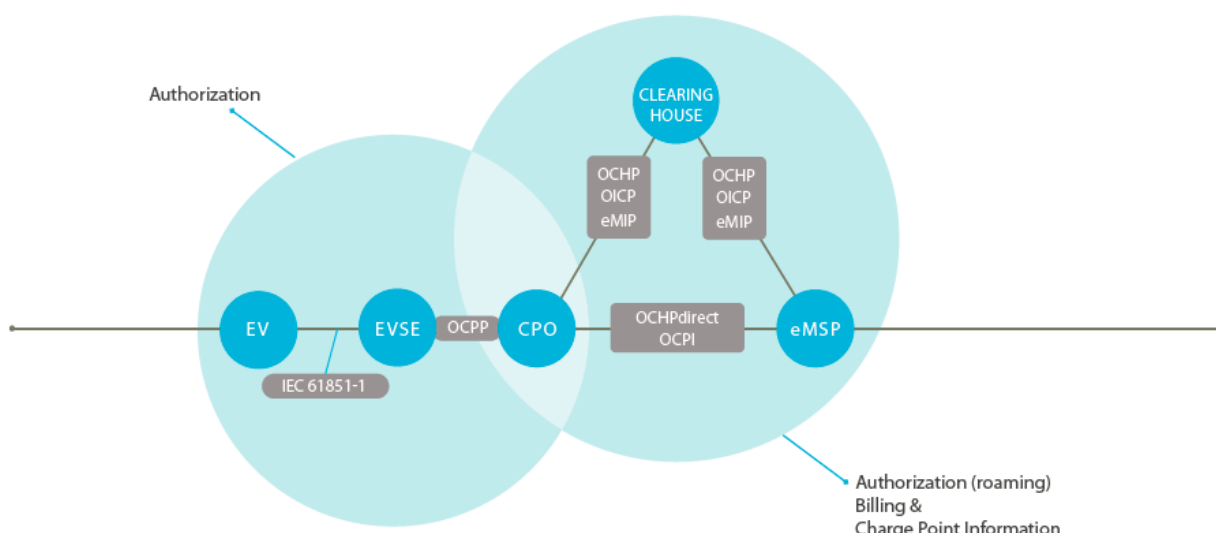


Figure 20: Basic EV charging

When using ISO / IEC 15118, authorization can be done using contract certificates between the EV and the charge point. This means that it is not required to validate the authorization token at the CPO (and EMSP). As a consequence, the connection to the EMSP is only necessary for

billing purposes (and for charge point information if applicable). This is also known as plug-and-charge.

As indicated in 6.1, currently no open standards / protocols are available for the OEM to communicate with the EV market chain. Currently more and more cars (not just EVs) are being equipped with a communication module to communicate with the OEM, for example for communicating battery status, updating car software or for reporting emergencies when the airbag is activated. A possible future scenario is that this communication module in the car will be used for communication with the EV market chain. This model, called the “Connected Car model”, could mean that EVs communicate directly with the EMSP and part of the current protocol functionality from EV via CPO to EMSP is replaced by this direct channel. For example, information concerning battery status, preferred time of departure and authorization could be communicated via this channel. This model is visualized in Figure 21.

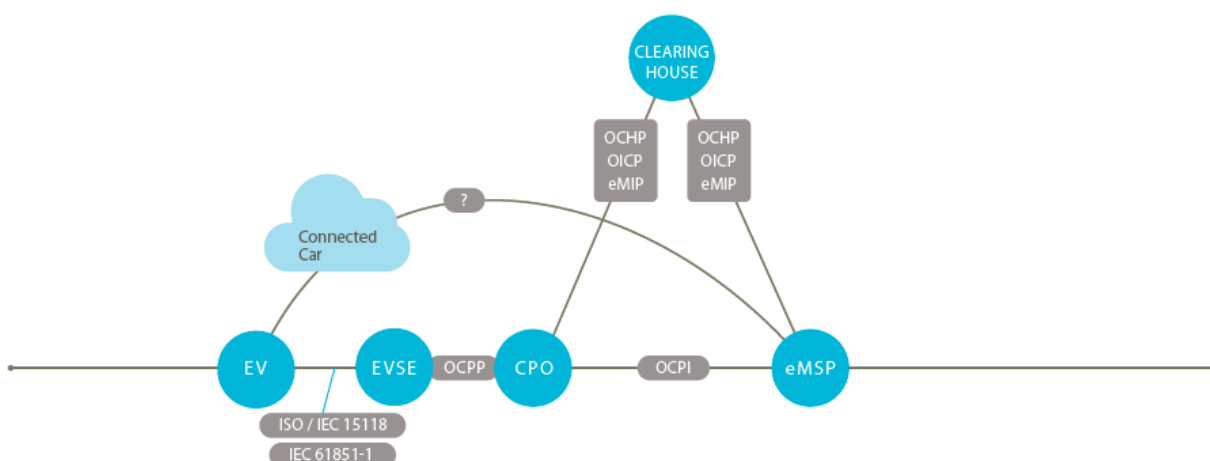


Figure 21: Connected Car model

6.4 Smart Charging

According to [CCE2012] and [EUDEL2015] the definition of smart charging 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.*”

Smart charging can be based on the input from the 3 stakeholders for which it can be an opportunity:

1. Customers
2. Power system
3. Society

When looking at the protocols under consideration not many customer inputs are directly visible. Input from the EV user can for example be “renewable energy only” or “I want to be charged for 75 % at 16.00h”. A number of EV related pilots in the Netherlands have shown that price is a very important factor on the EV user side. This means that from the protocols in this study, tariffing information is an important input for smart charging. Another important input could be a desired charging schedule from an EV user. However, this type of smart charging messages is currently only available in OCPI v0.4.

To maximize customer convenience, smart charging of EVs depends on two important pieces of information: the battery status (full / empty), usually referred to as the “state of charge” (SoC) and the planned time of departure (ToD) of the EV user. In the discussion in this chapter, the SoC will be used with a broader definition than in some protocols: this is not only the battery percentage left, but it is assumed that it also implies that the battery size is known. When only using these variables, the implicit assumption is that the EV user wants a full battery. If not, another variable, “energy amount requested” should also be taken into account. Many of the current smart charging solutions depend on this information and have different (non-standardized) ways of acquiring this information. Some implementations ignore this information, others may want to use it and use a best-guess if no information is available.

The second stakeholder is the power system or the role responsible for it. Inputs from the power system can be, for example, available capacity which usually comes from a DSO. In this study a number of protocols related to these inputs have been discussed in the smart charging chapter: OpenADR, IEEE 2030.5 and OSCP. Both OpenADR and IEEE 2030.5 have specific “demand response” functionality, which boils down to 1 “sending” system that sends out requests to adjust the power usage to which receivers can respond. The purpose of this is better matching demand (consumption) and supply of energy. An example application for demand response is to prevent problems in the grid.

The stakeholder society is primarily related to adapt charging based on the availability of renewable energy (see also [EUEL2015]). This is not directly visible in the protocols under consideration. However, this information could be incorporated in the price of charging and therefore indirectly in the tariff structures of the protocols.

When looking at the protocols from the perspective of smart charging the first notable observation is that when looking at the roaming platform protocols, only the Gireve platform in combination with the eMIP protocol has support for smart charging. This platform can get the SoC from the EV in case it is a Renault. The platform has a connection to the OEM platform. This setup is visualized in Figure 22. Please note that that DSO signals are currently only used in pilot setups and these are not yet legally enforced. Whether these are to be sent to the EMSP or CPO role, is not fixed. Therefore, two lines are drawn, from DSO to both CPO as well as EMSP.

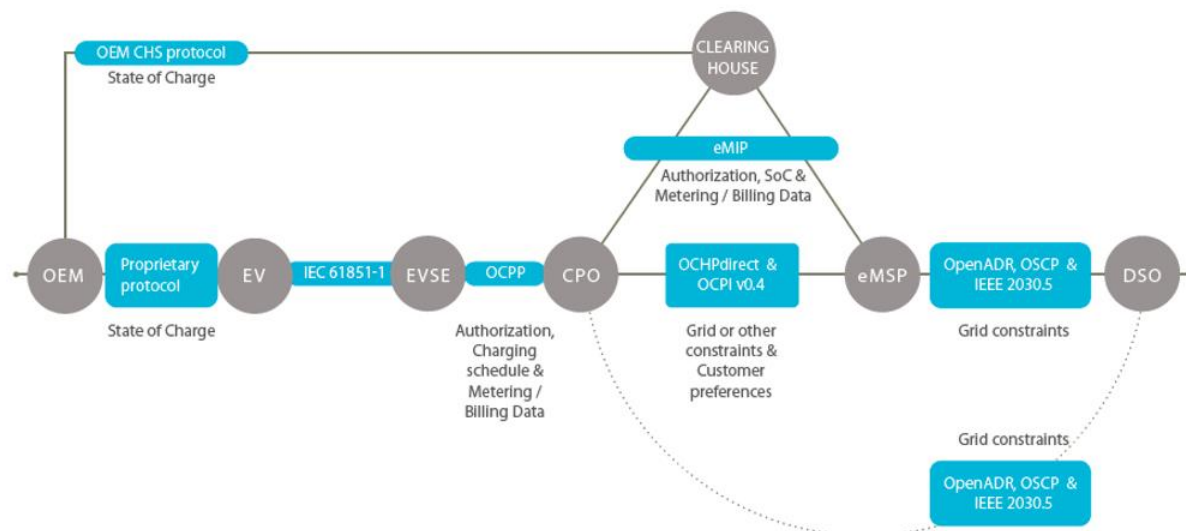


Figure 22: Smart charging using Gireve platform

This means that currently in this setup only one brand of EV's can be smart charged efficiently by using the SoC (i.e. Renault). This looks like a second step in the protocols related to smart charging: besides exchanging smart charging messages between EMSP and CPO, the addition of connections to OEM platforms for getting the SoC.

In the future the SoC (and perhaps the ToD as well), may be acquired from an EV using the ISO / IEC 15118 protocol. However, this has a dependency of both the charge point as well as the EV. Currently the market adoption is still low, so in the short term, this cannot be used. Once the ISO / IEC 15118 protocol is implemented (including the SoC functionality), a logical combination is visualized in Figure 23.

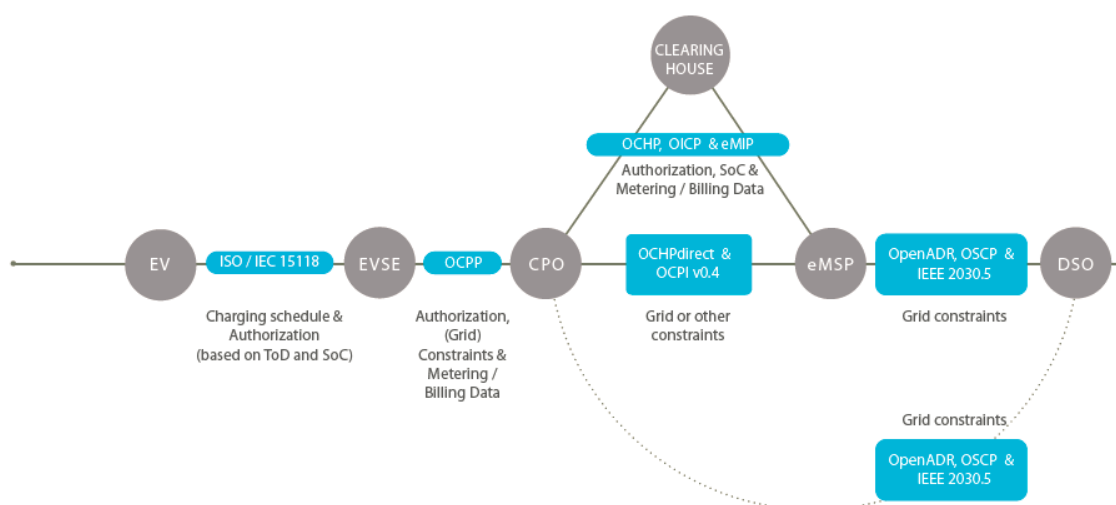


Figure 23: Smart charging using ISO / IEC 15118

This figure implies that part of the input for smart charging is to be communicated from the DSO on the right side and the EV on the left side to either the CPO or the EMSP. The ISO / IEC 15118 protocol also supports scheduling at the EV side, which means that the EV is able to communicate a charging schedule. One of the future scenarios therefore is that both the SoC and ToD information all come from the EV and the role of the EMSP is minimized to just handling billing. The CPO could be made responsible for scheduling based on the EV input and the grid limits from the DSO.

Please note that all figures implicitly assume that the required information can be sent using the OCPP protocol. Currently this is not yet possible for the ISO / IEC 15118 scenario.

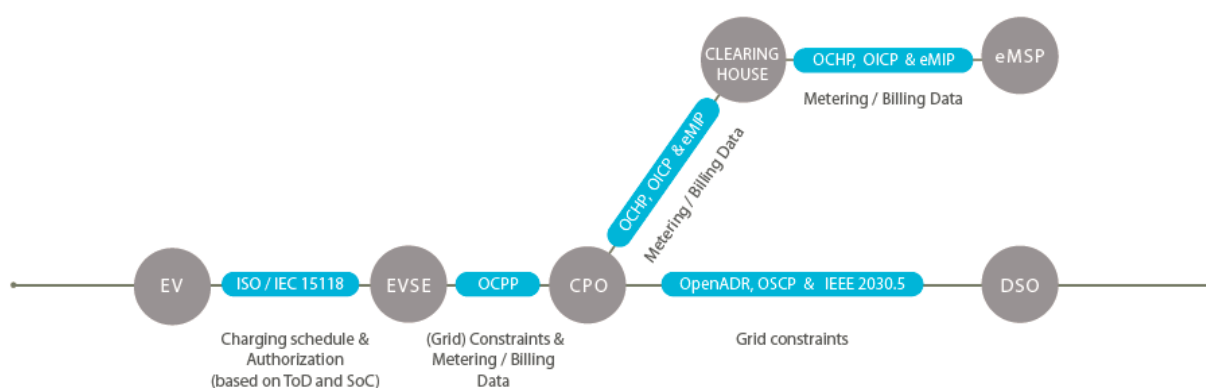


Figure 24: Smart charging based on ISO / IEC 15118 with minimized role of EMSP

6.5 Protocol relevance for smart grid from a DSO perspective

From a DSO perspective electric vehicles are a heavy load on the electricity grid. In some countries this is expected to lead to capacity problems in the coming years, once the number of EVs starts growing. From a DSO perspective it is therefore important that the protocols within the EV domain have some kind of possibility to make sure that the network will not break down. This could be done by informing market parties about the grid. Another possibility for the DSO is to take over control. This means that all protocols that support some form of smart charging that include a DSO role, are relevant. When looking at the protocols in this study, most of these are in some way related to smart charging. However, the fact that the DSO can use, for example, OpenADR or OSCP to send signals to market parties is not enough. Grid stability cannot be ensured if parties are free to ignore the signals meant to protect the grid. The market will require some form of regulation to enforce this.

The only protocols that are currently not directly relevant from a DSO perspective, are the roaming protocols without smart charging functionality. These impact the grid, but offer no way

of influencing. That is why they are irrelevant to DSO in the controlling sense, but are still indirectly relevant because of their impact on the grid.

When looking at smart grids in general, the IEEE 2030.5 protocol also adds functionality for in house devices. The relevance of this is limited, since most in house devices do not use much energy when compared to an EV. Furthermore, most devices do not have much flexibility compared to EVs: for most in house devices it is not an option to postpone the electricity usage. Experiments using smart washing machines have been executed in the Netherlands in the context of behavioral research. For this type of applications IEEE 2030.5 could be considered relevant.

6.6 Relation to home charging

The choice of protocols (except for the IEEE 2030.5 protocol) in this study implicitly has the assumption that the use of a Home or Building Energy Management Systems, (B/H)EMS, for controlling a charge point is excluded. If a charge point is not connected to the outside world, but only to an EMS, no direct control of charging is possible. Furthermore, since it might be located in house (i.e. in a parking garage), perhaps no authentication is required. This means that a lot of functionalities from the protocols described in this study are not necessary: parts of OCPP for authorization are not needed, roaming is not applicable and if the charge point is behind the home meter, billing might also not be applicable. As indicated in the beginning of this document, this study is primarily based on European experiences at ElaadNL. If a (B/H)EMS is taken into account, an example setup is shown in the figure below.

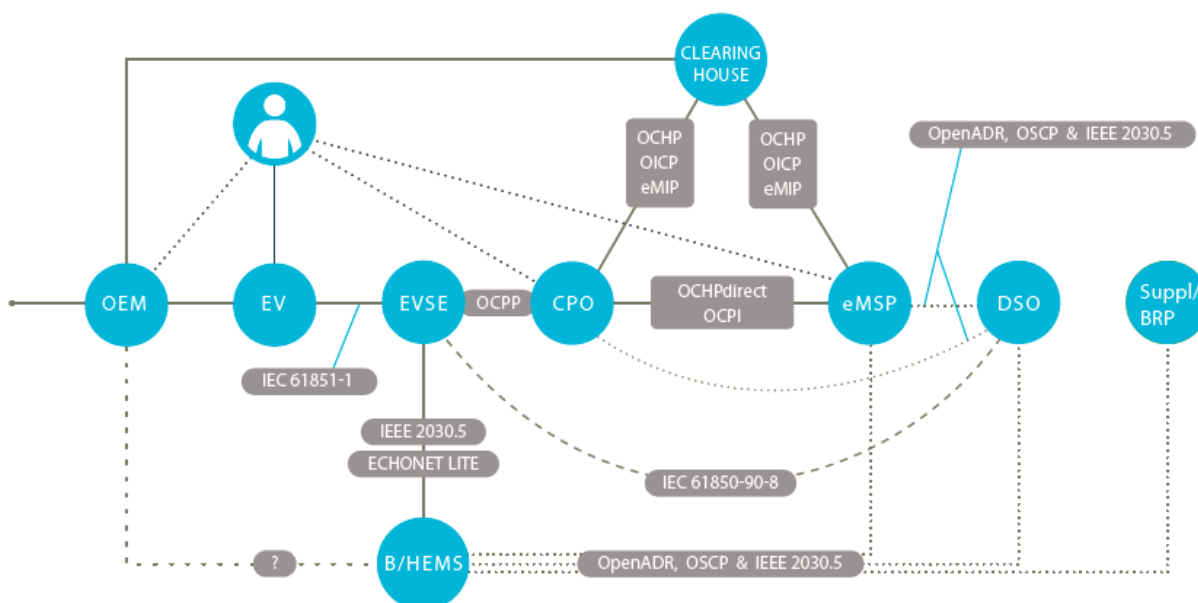


Figure 25: Example setup including (B/H)EMS

It is recommended to do more research on (B/H)EMS to incorporate these into the existing EV charging and smart charging chains that currently operative in Europe.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Research question 1: This question concerns the functionalities supported by the EV related protocols within the scope of this study. This question has been addressed in the chapters 5.1, 5.2, 5.3 and 5.4. The main functionalities are summarized in Table 3.

Table 3: Overview of protocol functionalities²⁸

	OSCP	OpenADR	OCPI v0.4	IEEE 2030.5	OCPP	61850-90-8	OCHP	OCPI 2.1	OICP	eMIP	IEC 61851	ISO 15118
PROTOCOL	SMART CHARGING				CS <-> CP		ROAMING				EV <-> CP	
Authorize charging session			•		•		•	•	•	•		•
Billing					•		•	•	•	•		
EV Charging											•	•
Handle registration		•		•				•				
Manage grid	•	•		•	•	•						
Operate Charge Point					•	•						
Provide charge point information			•				•	•	•	•		
Reservation			•		•		•	•	•			•
Roaming			•				•	•	•	•		
Smart Charging	•	•	•	•	•	•	•			•	•	•

The aspects of interoperability, maturity and market adoption have been added as separate paragraphs. These results are summarized in Table 4.

Table 4: Overview of maturity, interoperability and market adoption

	Version	Maturity	Interoperability	Market Adoption	Openness	Testing tool (dedicated / specific)	Certification (official testlab)
Smart Charging							
OSCP	1.0	Low	High	Low	Medium	No	No
OpenADR 2.0	1.1	High	Medium / High	Medium / High	High	Yes	Yes
OCPI	v0.4	Very low	Very low	Low	Low	No	No
IEEE 2030.5	2.0	High	Medium / High	Low	High	Yes	Yes
CS - CP							
OCPP	1.6	High	High	High	Medium / High	Yes	No
IEC 61850[90-8]	-	Medium	Low	Low	High	Unknown	Yes
Roaming							
OCHP	1.4	High	High	Medium / High	Medium	No	No
OCPI	2.1	Low	High	Low	High	No	No
OICP	2.1	High	High	High	Medium	No	No
eMIP	0.7.4	High	High	Medium	Low / Medium	No	No
EV - CP							
IEC 61851-1	-	High	High	High	High	Unknown	Yes
ISO / IEC 15118	-	Medium	High	Low	High	No	No

²⁸ O → Operating Charge Point using 61850-90-8: only the basics
 Smart Charging in OCHP: only OCHPdirect and only basics
 Smart Charging in eMIP: only 1 OEM (so only 1 car brand)

Research question 2: This question concerns which set of protocols is best applicable for which functionality in different types of situations. Due to the overlap between protocols, it is very difficult to say what protocol can be used in which situation: many combinations are possible and the exact requirements, which could include future ambitions, determine what protocol set should be used. In the chapters 5.1.5, 5.2.3 and 5.3.5 some guidance on the applicability of the protocols is given. Chapter 6 describes a number of possible protocol combinations for EV charging and smart charging.

However, a number of (main) conclusions can be drawn in this study:

- Roaming:
 - The next step for the roaming protocols seems to be the addition / extension of smart charging functionality. This is currently only available in the eMIP protocol.
 - A choice is to be made whether both point-to-point protocols or a clearing house type of communication is to be pursued for roaming.
 - A next step could be to connect multiple clearing house platforms.
- Smart Charging:
 - In the future, the State of Charge (and perhaps the Time of Departure as well), can be acquired from an EV using the ISO / IEC 15118 protocol.
 - For the short term (while waiting for wide scale adoption of ISO / IEC 15118) a second step in the protocols related to smart charging, could be the addition of connections to different OEM platforms for getting the SoC.
- Communication to the EV user is necessary for providing information, but could also be used to collect information (e.g. time of departure). Currently however, none of the protocols under consideration are aimed at the EV user.

A sub question of research question 2 concerns the protocol relevance for smart grid from a DSO perspective. This question is addressed in paragraph 6.5. There we conclude that most of the protocols are relevant either directly or indirectly.

7.2 Recommendations

Based on this study the following recommendation are made:

1. Put more work in the smart charging aspects of the existing roaming protocols. The functionality is currently far from serving one European market and is therefore not ready to enable smart grids throughout Europe.
2. Set a next step in roaming platforms. Some options are connecting the different platforms or merge platforms together. However, this is viewed from a technical perspective. It is recommended to also analyze the political and commercial interests, which may turn out to more predominant than the technical solution. Ultimately the

technical solutions will have to adapt to the limitations imposed by politics and commerce. At the same time, a technical solution may take into account that political and commercial interests are not a constant.

3. Referring to the previous point, it is recommended to start a separate study on this topic, perhaps looking from a more broad perspective:
 - a. Creating a proposal for a long term architecture vision concerning point to point solutions and clearing houses. This could for example be that we will end up with a hybrid model.
 - b. Setting up a roadmap that would make a gradual growth to the proposed solution possible.
 - c. Making suggestions for increasing the chance of acceptance of the solution.
4. To accelerate the adoption of smart charging in a user friendly way, the state of charge and time of departure are of importance. The state of charge will become available when using the ISO / IEC 15118 protocol. Based on the expectations of the market penetration of this protocol, it is recommended to temporarily get the state of charge from the OEMs, perhaps via roaming platforms, to prevent rapid growth in connection between parties in the EV market. Alternatively a clearing house-like centralized system that offers a standard SoC interface to other systems could be investigated. This could abstract from vendor specific APIs. Again commercial interests should be taken into account here.
5. Protocols for communicating grid limits or dynamic pricing are already available. However, current legislation in most countries is not yet prepared for dynamic pricing or setting grid limits from a DSO. It is recommended that this legislation is changed to make it possible to utilize the flexibility that EVs offer.
6. Based on the maturity of the different smart charging protocols it should be explored whether the specific use case supported by the OSCP protocol can also be covered by OpenADR or IEEE 2030.5 messages, with an additional behavior specification / implementation guide.
7. In Europe little / no experience with Energy Management Systems is available. It is recommended to include an EMS in new pilot projects. A possible candidate for this could be IEEE 2030.5. However, as mentioned earlier, to our knowledge, no production implementations currently exist.
8. The impact of power system operator control signals (e.g. 61850-90-8) in case of a critical situation in the electricity grid, is to be further investigated due to its impact on the rest of the EV chain. This impact can be on for example billing, but also on charge point operation (prevent false positive for charge point malfunctioning).
9. When looking at the protocols under consideration, it should be explored whether it is useful to extend / develop protocols that are more closely targeted at EV user communication. This could be directly explored, but also indirectly by creating an overview that EV user related datastructures / fields / elements are currently used in the different protocols.
10. Referring to 9, in general it is recommended to explore datamodels / datastructures that are used in the different protocols for improved interoperability when using combinations of protocols.

11. Additional criteria could be added to compare protocols, such as scalability, the extent to which protocols are “similar” or “compatible” to other protocols in the EV chain (e.g. similar datamodel etc.).
12. Add a number of additional protocols to this comparison, such as: DIN SPEC 70121, CHAdeMO, ECHONET-Lite and IEC 61851-24.
13. In the previous chapter the roles of DSO, TSO and BRP were briefly addressed. A next step could be to explore the current and future relation / dependency between these roles in more detail, specifically in relation to EV.
14. To have better insight which protocol combinations will become more likely in the near future, it is recommended to get more input from OEMs about future plans.

LITERATURE

Protocol documentation

[OpenADR2015]: OpenADR ALLIANCE: OpenADR 2.0 Profile Specification B Profile, 2015

[OCPI2016]: EVIOLIN: Open Charge Point Interface 2.1, 2016

[OCPI2014]: EVIOLIN: OCPI, NDR & CDR Interface 1.0 (DRAFT v4), 2014

[eMIP-SC2015]: GIREVE-JMR: eMIP Protocol Implementation Guide - Smart Charge, 2015

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[OICP-EMSP2016]: HUBJECT: Open InterCharge Protocol for Emobility Service Provider Version 2.1, 2016

[IEC-61850-2015]: IEC: IEC 61850-90-8 TR:Communication networks and systems for power utility automation - Part 90-8: Object model for electric mobility, 2015

[ISO-IEC15118-2-2014]: ISO-IEC: ISO 15118-2: Road vehicles - Vehicle-to-Grid Communication Interface - Part 2: Network and application protocol requirements, 2014

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[eMIP2016]: RIVES, J.-M.: eMIP Protocol Protocol Description, 2016

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[SEP2-2013] IEEE, IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard, 2013.

[SMC-SEP2013] SAE, Communication for Smart Charging of Plug-in Electric Vehicles using Smart Energy Profile 2.0, 2013

Other context related documents

[CCE2012] Smart Grid Coordination Group - Sustainable Processes, CEN-CENELEC-ETSI, 2012.

[EUEL2015] Eurelectric, Smart charging: steering the charge, driving the change, 2015

Websites of protocol authors / publishers

Protocol	Website
Open Smart Charging Protocol (OSCP)	www.openchargealliance.org
OpenADR	https://www.oasis-open.org/committees/energyinterop/ and http://www.openadr.org/
Open Charge Point Interface (OCPI)	http://en.nklnederland.nl/ https://github.com/ocpi
Smart Energy Profile (SEP) ²⁹	http://www.ieee.org/
OCPP	www.openchargealliance.org
IEC 61850(90-8)	http://www.iec.ch/
Open Clearing House Protocol (OCHP)	http://www.ochp.eu/
Open Charge Point Interface (OCPI)	http://en.nklnederland.nl/
Open InterCharge Protocol (OICP)	https://www.hubject.com/
eMobility Inter-Operation Protocol (eMIP)	http://www.qireve.com/
IEC 61851-1	http://www.iec.ch/
ISO / IEC 15118	http://www.iso.org/ & http://www.iec.ch/

²⁹ This protocol is sometimes referred to as 2030.5.

APPENDIX A: FUTURE PLANS PER PROTOCOL

A number of reviewers of this document, gave feedback that included remarks like "we are working on functionality X in the next version". I have not taken these functionalities into account for this version to make a fair comparison. However, this information is relevant, so the table below gives an overview of the future plans per protocol:

Table 5: Future plans per protocol

Protocol	Functionality	Version	Due (estimated)	Remarks
OpenADR 2.0B	Distributed Energy Resource management functions	1.2	Q3 2017	Plan is to add signal types to enable further DER related functions. Further, an addendum document will contain Transactive Energy messages (e.g. energy bidding, etc.)
IEEE 2030.5	Smart inverter management	N.a.	Expected to "go to ballot" in early 2017.	An update that will incorporate new capabilities required by the state of California for smart inverter management
OCPD	<ul style="list-style-type: none"> • Security enhancements • ISO / IEC 15118 support • Support for external smart charging control signals • Device model • Tariffing and pricing 	T.b.d.	2017	
OCPD	<ul style="list-style-type: none"> • Bug fixes • Smart charging 	2.1.1 and 2.2	2017	

	<ul style="list-style-type: none">• Better connection with roaming hubs• Multiple languages• Tariffing• Correcting CDRs• Charge point groups• Enabling module based implementations• Support for virtual operators and service providers (including navigation service providers)• Module for supporting data collection for data analysis purposes			

APPENDIX B: PROTOCOL USE CASE TABLE

Below you will find a complete overview of the detailed use cases supported by the protocols in this document, as also visualized in the protocol use case diagrams:

Protocol	Smart charging				CS <> CP		Roaming				EV <> CP	
	OSCP	OpenADR	OCPI v0.4	IEEE 2030.5	OCPP	IEC61850-90-8	OCHP	OCPI 2.1	OICP	eMIP	IEC 61851-1	IEC 15118
Use cases												
(De)register			•					•				
(Provide) Charging details												•
AC charging with load levelling based on High Level Communication												•
Approve CDR							•					
Authorization at EVSE using ext. credentials performed at the EVSE												•
Authorization at EVSE using ext. credentials performed with help of SA												•
Authorization using Contract Certificates performed at the EVSE												•
Authorization using Contract Certificates performed with help of SA												•
Authorize and store subscription			•									
Authorize charging session			•		•		•	•	•	•		•
Billing					•		•	•	•	•		
Certificate Handling												•
Certificate install												•

Distribute DR event		•											
Distribute dynamic prices		•											
Download CDR							•		•	•			
Download charge point information							•		•				
Download full list of roaming authorisation data							•			•			
Download live status information							•		•				
Download Tariff Information							•			•			
Download updates in roaming authorisation data							•						
End-of-charging process													•
Energy flow reservation				•									
EV charging											•		•
EV-charge point communication setup													•
Exchange endpoints							•	•					
Exchange of Authorisation Data							•		•	•			
Exchange of Charge Point Information							•		•	•			
Exchange of Parking Spot Information							•			•			
Exchange of Tariff Information							•						
Exchange raw billing (charging) data							•		•				
Exchange versions								•					
Exchanging metering data	•	•		•		•							
Execute Smart Charging commands						•							
Get current vehicle status										•			

Get roaming partners interface definitions								•						
Hand out capacity "budgets"	•													
Handle OCPI Registration									•					
Handle registration		•		•					•					
Handle VEN registrations		•												
Identification, authorization and authentication														•
Influence grid usage	•	•												
Inform driver of actual session costs			•						•					
Live status interface								•		•				
Maintain local authorization list						•								
Maintenance of Charge Point						•								
Manage charge point availability						•								
Manage charge point firmware						•								
Manage DER				•										
Manage grid capacity by communicating cable capacity forecasts	•													
Manage grid capacity by communicating price signals		•												
Manage grid	•	•		•		•	•							
Manage power consumption of Charge Point			•			•		•						•
Operate Charge Point						•	○							
Optimized charging with scheduling at EV														•

Remote Control of Charge Point								•			•		
Remote start / stop transaction					•			•	•	•			
Remove (own) authorisation data										•			
Remove (own) charge point information										•			
Report a data or compatibility discrepancy								•					
Report remote (emergency) stop, suspend, restart charging											•		
Request capacity / Indicate needs	•												
Request Capacity Forecast	•												
Request charge needs											•		
Request charge point information per hierarchical level (charging pool, station, EVSE, connector)											•		
Request charging process information for a customer								•					
Request current live status								•			•		
Request current live status per hierarchical level (charging pool, station, EVSE, connector)											•		
Request smart charging for a driver			•										
Request the CHS to authorize one single token for roaming								•		•	•		
Reservation			•		•			•	•	•			•
Reservation of charge point (administratively)			•					•	•	•			
Reserve a charge point for a driver			•					•	•	•			

(administratively)														
Reserve charge point (technically)						•								•
Respond to DR event		•												
Resume to Authorized Charge Schedule														•
Retrieve list of EVSE's located in a given area and fulfilling a set of criteria													•	
Revise CDR										•				
Roaming			•							•	•	•	•	
Schedule based charging				•		•								•
Select a charge point										•				
Send Aggregated Usage	•													
Send Capacity Forecasts	•													
Send charging dispatch signal		•												
Send Charging event										•				
Send customer bid level signal		•												
Send data report		•												
Send demand charge signal		•												
Send DSO Heartbeats	•													
Send electricity price signal		•												
Send energy price signal		•												
Send Event Signal		•												
Send heartbeats to CHS													•	
Send load control signal		•												
Send load dispatch signal		•												

Send metadata report		•												
Send Opt-In / Opt-Out schedules		•												
Send remote commands to location / EVSE								•	•					
Send Report		•												
Send reset charge point message						•								
Send simple signal		•												
Send Unlock connector command						•								
Sending text messages					•									
Set (own) interface definition									•					
Set charge point availability						•								
Set resource availability		•				•								
Set tariff restrictions (e.g. maxEnergy, maxDuration)									•					
Single Authorization Requests						•			•			•		
Smart Charging	•	•	•	•	•	•	•	○				○	•	•
Start / stop transaction						•								
Start of the charging process													•	•
Start of the charging process with concurrent IEC 61851-1 and HLC														•
Start of the charging process with forced HLC														•
Subscribe to charge point information				•										
Subscribe to sub-set of charge points				•										
Target setting and Charging scheduling														•

Trigger message from charge point						•								
Update (own) authorisation data								•		•				
Update Tariff Information								•						
Update the live status of stations								•		•	•			
Update the live status of stations per hierarchical level (charging pool, station, EVSE, connector)												•		
Upload (own) authorisation data								•		•	•			
Upload (own) charge point information								•		•	•			
Upload Charge Data Records								•			•			
Upload charge point information per hierarchical level (charging pool, station, EVSE, connector)												•		
Upload Tariff Information								•			•			
Validate authorization						•								
Value-added services														•
Vehicle to grid support														○

EV RELATED PROTOCOL STUDY

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