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Executive Summary

This deliverable reports the results from the work conducted in Task 3.2 to define a number of architectures relevant for the COTEVOS project based upon the interoperability assessment conducted in Task 3.1.

In this document we describe different architectures relevant for the COTEVOS-project:

1. The COTEVOS basic reference architecture (Section 3.1), which describes all the actors and their interfaces in the e-mobility system. This architecture provides a common and unambiguous context for all use cases and test cases developed in the COTEVOS project. We develop interface reference architectures which describe the COTEVOS basic reference architecture from four viewpoints: the EV-EVSE physical interoperability viewpoint, the charging infrastructure viewpoint, the e-mobility Service Provider (EMSP) interfaces viewpoint, and the metering viewpoint.
2. The COTEVOS Service architecture (Section 2.3), which describes the e-mobility system architecture from a (business) service point-of-view. This architecture describes all the services and functions supported by the basic reference architecture and allows us to define the responsibilities of each actor in the e-mobility system, and will therefore constitute the basis for a stable interface reference architecture.
3. The COTEVOS Lab architecture (Section 4.2), which describes a common and unambiguous COTEVOS architecture that is used as a (non-compulsory) reference in the labs of the partners. The idea behind a common lab architecture is that all partners that have not yet chosen for a specific lab architecture can adopt the proposed architecture. Moreover, for the partners that adopt the COTEVOS Lab reference architecture it will be easier to re-use each other's test tools.

The basic reference architecture was initially formulated based upon the work of Task 3.1, and building upon the use cases defined in WP 1 and the evaluated standards from WP 2. Furthermore, it builds upon the results from e.g. FP7 GreenEmotion, the EMI3 group, and the EU Smart Grid-Coordination Group.

In the process of developing the COTEVOS Lab Architecture we combined the envisioned lab architectures from all partners. In the course of this process we developed enhancements to the basic reference architecture through the introduction of additional interfaces and actors.

At this stage we found it useful, and necessary, to develop a service architecture where services are described independently from actors, but can easily be mapped back to actors in the e-mobility system. This allows the approach to be more generalised, to deal with situations where choices are available for which actor performs which function, for example to deal with potential differences in the roles of actors between different EU member countries.

The basic reference architecture has been accepted and agreed upon by all partners in the COTEVOS project. It is well aligned, and shares many similarities with the work produced in the Green eMotion FP7 project, eMI3, and the CEN/CENELEC/ETSI group on Smart Charging and the Smart Grid Coordination Group's activities mandated in M/490 by the European Commission.

The different test cases that are to be implemented by the labs show a neat coverage of the available test cases. It shows that each lab has a different focus (and expertise), together covering the complete e-mobility ecosystem.

The missing standards ('gaps') identified in the basic reference architecture can be dealt with in the laboratories by taking into account several currently existing implementations and combinations of EVSE Operator, EMSP and Clearing House as a reference. Since the Smart Grid system is much less specified, testing the interfaces of the key actors in this Smart Grid system (e.g. the Energy Supplier and DSO) is difficult. Real implementations do not exist yet, but several use cases are available. Combining this with the Smart Grid knowledge of the COTEVOS partners and their communities will allow COTEVOS to define smart charging use and test cases, covering expected future functionality.



Some of the identified gaps can be overcome by taking the current status of standards and standardisation activities into account. Since one can only test according to a specification or standard, just (expected) use cases can be tested if neither specification or standard are available.

There is no gap in the COTEVOS Lab Architecture itself. It covers all current and foreseen actors, systems and infrastructures. Furthermore, it shows that COTEVOS is able to test real EV's, EVSE's and EV users in the different laboratories, and as such perform round robin tests for EV's and EVSE's which will be completed in WP 4.

All other actors are either simulated or emulated to create a functional interoperability test. All simulated or emulated actors are available and implemented in at least two laboratories.



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Abbreviations and Acronyms

Table 1 Acronyms

BMS	Battery Management System
BRP	Balance Responsible Party
CPLT	Control Pilot Line
DoW	Description of Work
DSO	Distributed System Operator
DUT	Device Under Test
EC	European Commission
EMG	Energy Management Gateway
EMSP	Electro Mobility Service Provider
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
EVSEO	Electric Vehicle Supply Equipment Operator
EMSP	E-mobility Service Provider
GA	General assembly
GUI	Graphical User Interface
IOP	InterOperability Profile
KPI	Key Performance Indicator
MB	Management Board
OCHP	Open Clearing House Protocol
OCPP	Open Charge Point Protocol
OSCP	Open Smart Charging Protocol
OEM	Original Equipment Manufacturer
PC	Project Coordinator
PE	Protective Earth
PWM	Pulse Width Modulation
QA	Quality Assurance
QAP	Quality Assurance Plan
QAS	Quality Assurance System
QM	Quality Manager
QMO	Quality Management Office
QO	Quality Objective
RFID	Radio Frequency Identification
SGAM	Smart Grid Architecture Model
SGCG	Smart Grid Coordination Group



SOC	State Of Charge
TB	Technical Board
TM	Technical Manager
WP	Work package
WPL	Work package leader



1. Introduction

1.1. Scope of the document

This D3.2 deliverable collects the results of the work performed in Task T3.2 in Work Package 3 of the COTEVOS project.

In this document we describe different architectures relevant for the COTEVOS-project:

1. The COTEVOS basic reference architecture (Section 3.1), which describes all the actors and their interfaces in the e-mobility system. This architecture provides a common and unambiguous context for all use cases and test cases developed in the COTEVOS project. We develop interface reference architectures which describe the COTEVOS basic reference architecture from four viewpoints: the EV-EVSE physical interoperability viewpoint, the charging infrastructure viewpoint, the e-mobility Service Provider (EMSP) interfaces viewpoint, and the metering viewpoint.
2. The COTEVOS Service architecture (Section 2.3), which describes the e-mobility system architecture from a (business) service point-of-view. This architecture describes all the services and functions supported by the basic reference architecture and allows us to define the responsibilities of each actor in the e-mobility system, and will therefore constitute the basis for a stable interface reference architecture.
3. The COTEVOS Lab architecture (Section 4.2), which describes a common and unambiguous COTEVOS architecture that is used as a (non-compulsory) reference in the labs of the partners. The idea behind a common lab architecture is that all partners that have not yet chosen for a specific lab architecture can adopt the proposed architecture. Moreover, for the partners that adopt the COTEVOS Lab reference architecture it will be easier to re-use each other's test tools.

These architectures are based on the evaluation and specification of the interfaces defined in Task 3.1. The development of these architectures is a prerequisite for developing tests and procedures which will be done in Tasks 3.3 and 3.4. and in WP 4 of the COTEVOS project, allowing these to use a common and unambiguous context, vocabulary and understanding of the e-mobility system .

1.2. Structure of the document

This document consists of three main chapters (Chapters 2, 3 & 4) followed by conclusions (Chapter 5).

In Chapter 2 we define the E-mobility Actors and their Services. We begin by describing the functional requirements for the basic reference architecture and then introduce the actors involved. Following this we perform an architectural analysis starting with the physical layer. Subsequently the business layer is analysed in the context of the use cases from WP 1. From that analysis the functional layer is developed, where services are described independently from actors, but can easily be mapped onto actors in the system.

In Chapter 3, from the layered views described in the previous chapter we define the COTEVOS basic reference architecture which takes the key components required to describe the use cases investigated by the COTEVOS project. The interfaces present in the reference architecture are analysed by slicing the architecture into four areas, each addressing a different viewpoint. These are:

- Physical viewpoint which addresses the physical interface between the EV and the EVSE.
- Physical + EVSE Operator viewpoint which addresses the interface between the EV-EVSE and the EVSE backend systems of the EVSE operator.
- EMSP viewpoint which addresses interfaces of the systems that implement roaming, basic or smart charging.
- Metering viewpoint which addresses the interfaces needed for metering.



In Chapter 4 we describe the envisioned lab architectures from the task partners (AIT, TNO, RSE, TECNALIA). These are combined to form a COVETOS lab architecture which is described in detail, before an analysis of the commonalities and gaps in actors and test cases between task partners is presented.

Chapter 5 closes the report and presents the conclusions of this work.



2. E-mobility Actors and their Services

In this chapter we identify the main actors and services in the e-mobility ecosystem that are required to specify the use cases from WP 1 in more detail and subsequently allow the corresponding test cases to be derived.

2.1. Requirements for the basic reference architecture

Use cases and test cases describe a list of interactions between one or more roles or actors and a system, to achieve a goal [9]. The 'system' here is the e-mobility system, which is built-up from all kinds of subsystems (i.e. system actors) and parties (i.e. human actors) that are (presumed to be) present in the market. To create an interoperable system in which all parties can participate it is of utmost importance that they all speak the same language. The basic reference architecture provides this common language for the COTEVOS project and its partners, and subsequently all parties that built upon the results from COTEVOS.

Therefore the requirements for the basic reference architecture are as follows:

1. Provide a common and unambiguous context for COTEVOS in the form of a basic reference architecture.
All COTEVOS partners agreed to use it when specifying use cases and test cases.
2. Reflect the current and future e-mobility system in Europe
The basic reference architecture should not only describe the future system but also fit the current real world situation.
3. Describe the responsibilities of each actor in the system.
When the responsibilities of all the actors are clear the interfaces between the actors will stabilize, creating a future proof architecture.

2.2. Actors

The E-mobility Reference Architecture is actor-based. These actors come from the use-cases defined in COTEVOS Deliverable 1.1 [1], other EV reference architectures (M/468 Smart Charging, M/490 Smart Grid, FP7 Green eMotion, eMI3) and from the current European electricity market.

The architectural analysis starts with the physical layer (or component layer, which is the lowest layer in SGAM as defined in the M/490 report Smart Grid Architecture [10], see Figure 1), since the physical entities are a given in all use cases. Subsequently the business layer is analysed in the context of a use case, which shows the business actors in the system and some of the interactions between them (the top layer of SGAM). From that analysis the function layer is developed. This analysis is input for a service view on the use case, which is independent from the actors, but can easily be mapped back to actors in the system. Based on the identified services, the information layer and subsequently the communication layer can be developed, showing the information objects and communication protocols required to implement the use case.

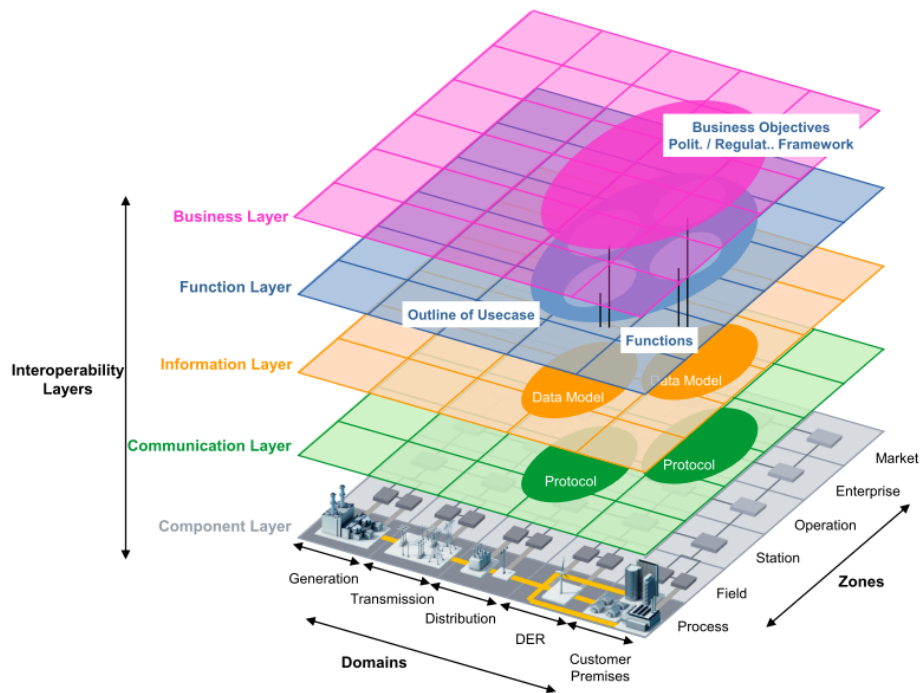


Figure 1: The SGAM - Smart Grid Architecture Model [10]

2.2.1. Actors related to the physical infrastructure / Component layer

The physical component layer is depicted in Figure 2 and shows the physical entities or system actors in the use case: an EV, an EVSE (or charge pole), a grid and a power supply/power plant. It is important to take the ownership of the physical power infrastructure into account, thus linking physical entities to businesses. The figure shows four (business) actors that are present in any use case related to electrical vehicles: EV User, EVSE Operator, DSO and Energy Supplier. From a physical point of view the electricity is supplied by an Energy Supplier. As a side note: the owner of the EV is not always the user of the EV, therefore the EV user is used in this figure.

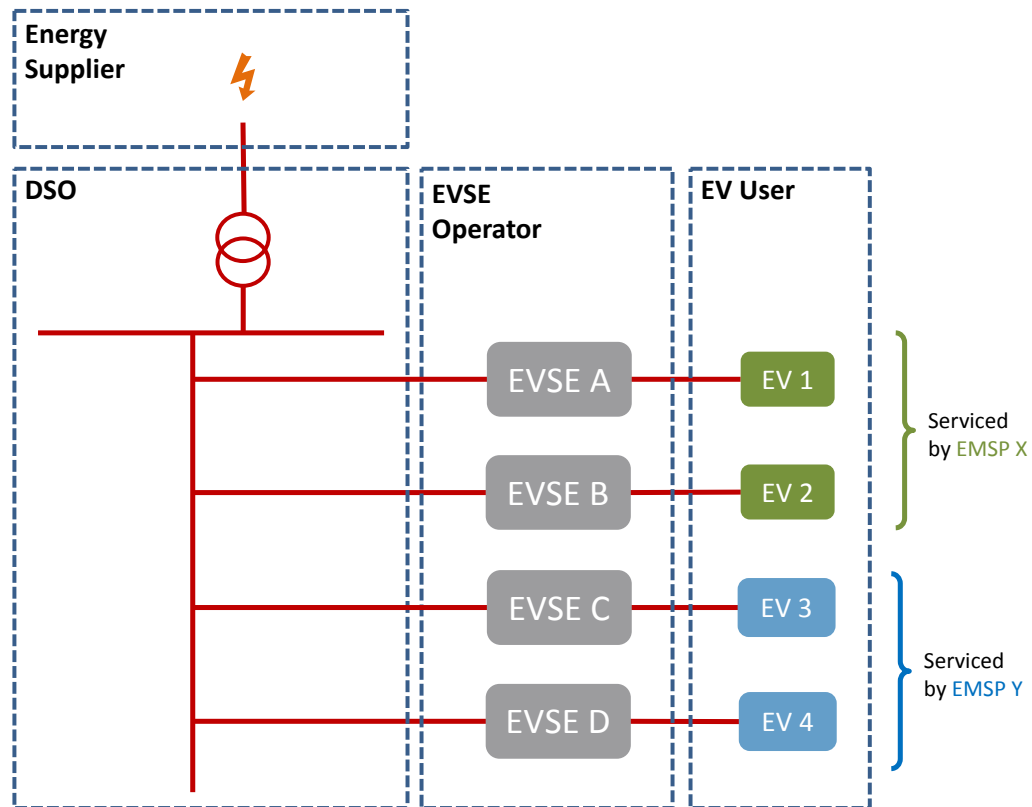


Figure 2 Actors related to the physical layer (example with four EVs and four EVSEs on one feeder line of the DSO)

To sum up, the following actors are present in this view

- **EV user**
 - o the person that wants to charge the EV
- **EVSE** (Electric Vehicle Supply Equipment)
 - o The charging station or charging spot¹ used to charge the EV
- **EVSE Operator**
 - o Manages the EVSEs but likely also implements basic charge functionality (e.g. authorization of charging) and smart charging functions and depending on the business model additional value-added services (see also “EMSP” in section 2.2.2)
- **DSO** (Distributed System Operator)
 - o The DSO operates the distribution grid in order to deliver electricity to the end users.
- **Energy Supplier**
 - o Supplies electricity. To keep the architecture manageable, this actor is also used in the other views, but then providing energy from a contractual point of view (i.e. it is not generating the energy itself).

2.2.2. Business layer

The current European electricity market is also an important starting point, as it reflects how the current electricity system is implemented. A challenge in the modelling of the Market is that the actors' responsibilities that are present in the market differ among the EU member states (e.g. a DSO in the UK has different responsibilities than a DSO in the Netherlands).

¹ Charging station: as part of EV supply equipment permanently connected to fixed electrical installation, and charging spot: interface (for connection to EV) as part of charging station which enables charging of one EV at a time. A charging station may comprise one or several charging spots



Fortunately, the ENTSO-E/Ebix/EFET organisations have created a harmonized electricity market role model, describing the main roles required for the current electricity system, which is compatible among the EU member states. This model can be found in [2] and is used as a basis for the Smart Grid Conceptual model in M/490 [3].



Figure 3: Harmonized Electricity Market Role Model (HEM-RM) Source: [3]

Within the Smart Grid Coordination Group² this model is used extensively to create market models compatible within the entire EU, and from that point of view relevant for EV interoperability among the EU member states (see Figure 3). It is mature and used as a starting point for most Smart Grid systems and architectures. Since the HEM-RM models the whole electricity market, the following roles can be identified as actors in this reference architecture that are relevant for COTEVOS:

- **Markets** (green in Figure 3), facilitates buying and selling of energy, capacity and flexibility.

² Mandate (M/490) of the European Commission



- **Energy Supplier**, which is based on one or more roles present in the Energy Services (yellow in Figure 3) conceptual domain. This actor contractually delivers the energy produced by the producers (e.g. bulk generators) to the grid users (in our case via the EMSPs or EVSE Operators to the EVs) and acts on the Energy Markets to procure energy, grid capacity and/or flexibility. All Energy Suppliers have a Balancing Responsibility regarding their grid users [2].
- **Grid Operator, Grid Access Provider**: to operate the distribution grid and facilitate a stable power system. These roles together often correspond to a **Distribution System Operator (DSO)**, among other responsibilities of a DSO (depending on the Member State's regulations e.g. Metering Operations). This role was already identified in the physical view, and shows the importance of this role in several views.
- **Grid Users** (i.e. Consumer and in V2G scenarios also Producer): this role contracts the right to consume and/or produce at an Accounting Point (in HEM-RM terminology). For public charging this will be the **EVSE Operator** (since it needs to be a legal party). For private/home charging this is the legal owner of the accounting point (e.g. the EV User's employer at the company parking or the EV User itself at home). Each Accounting point is also a metering point where the amount of energy consumed/produced is measured.

When diving into the EV use cases itself the following prominent actors are present:

- **EMSP**
 - **E-Mobility Service Provider** (in some sources also named EV Service Provider (EVSP): has a contract with the EV user and provides EV charging services to the EV user.
 - May provide (depending on the business models) additional value-added services to the EV user, among others:
 - Search for EVSEs and reservation of charging spot
 - Navigation services
 - V2G services
 - Flexibility Aggregation services
 - Load management / energy procurement and planning
 - Multiple EMSPs can service each individual EV user
- **E-Mobility Clearing House**
 - E-Mobility Clearing House service offers clearing services between different EMSPs and EVSE Operators and implements national and/or international roaming services.
- **Original Equipment Manufacturer (OEM)**
 - Offers OEM-specific services (e.g. maintenance services) to the EV and the owner/user of the EV.
- **Flexibility Operator**
 - supply flexibility services to the grid (e.g. DSO) by using the flexibility made available, for example through the EV ecosystem (e.g. an EVSE-O or EMSP role)

To sum up: the following actors are present in COTEVOS' basic reference architecture:

1. EV User
2. EVSE
3. EVSE Operator
4. DSO
5. Energy Supplier
6. Energy Markets
7. EMSP
8. E-Mobility Clearing House
9. OEM
10. Flexibility Operator

How the actors are related to each other is presented in Chapter 3.

Key is the role of the EMSP actor. Multiple parties in the market could provide (some of) the services of this actor and/or some of the value added/additional services listed above. For example the energy retailer could provide this service to EV users allowing them to choose from a certain renewable energy mix, but also a DSO could provide this service incorporating grid congestion mechanisms, or similarly the EVSE operator could provide charge pole reservation or smart charging services. To



make all these different service combinations possible, without introducing new interfaces or actors, separation of concerns³ is key, and therefore the actors (and in particular the EMSP and EVSE Operator) is decoupled from any currently existing parties in the market.. This process is described in the next section.

2.3. Service and function layer – The Service architecture

The Service architecture allows for a separation of concerns within the e-mobility system and shows which main services, functions and interfaces are required when dealing with the use cases in COTEVOS (i.e. it combines the functional layer and the communication layer in SGAM). Each service provides specific functions. In Figure 4 these services are visually represented by boxes, where the corresponding functions are bullet-wise listed inside the boxes and where other services that are needed to implement those functions are connected by lines. The proposed view allows the use cases to be defined in terms of services instead of actors or physical power infrastructure, making a functional specification independent from its deployment. This means that the interfaces between the services can be defined (and will be stable), without knowing the actual allocation of services to actors in the (e-mobility) market. Furthermore, the figure helps identifying gaps with respect to interfaces that need to be standardized between services and their actors.

³ http://en.wikipedia.org/wiki/Separation_of_concerns for a detailed description

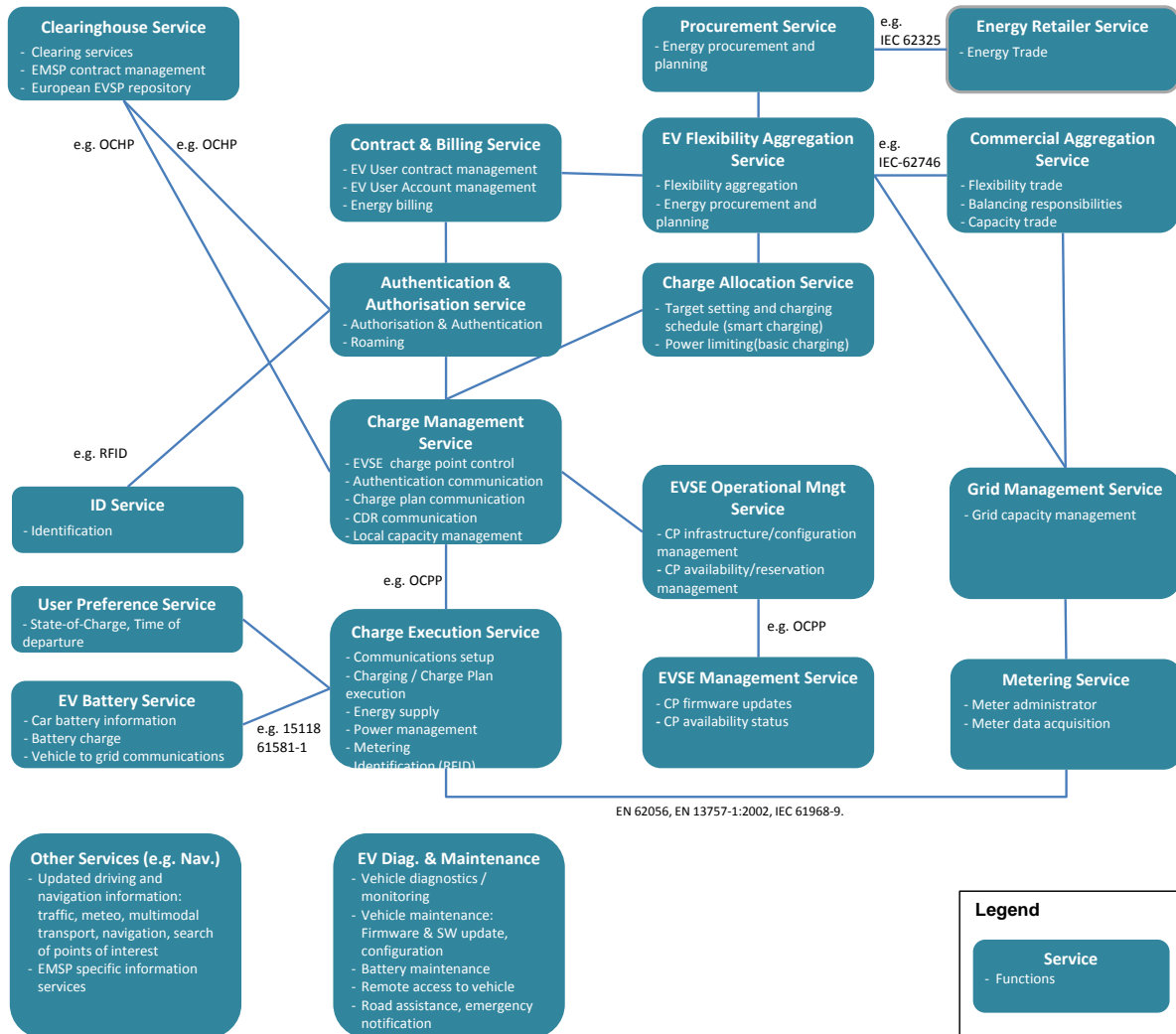


Figure 4: Service architecture of the EV ecosystem

The service architecture is of great help when specifying functionality and interfaces. However, when further detailing of use cases is required, then the number of sub-services and functions starts to become so large, that it cannot fit in an easy-to-understand figure. Therefore, the identified main services are mapped again on the actors that were identified earlier. This means that for each actor the services it could offer are identified and assigned in the context of the COTEVOS project. This means that within the COTEVOS project it will be clear what services each actor offers.

A possible mapping of services on actors is depicted in the following figure:

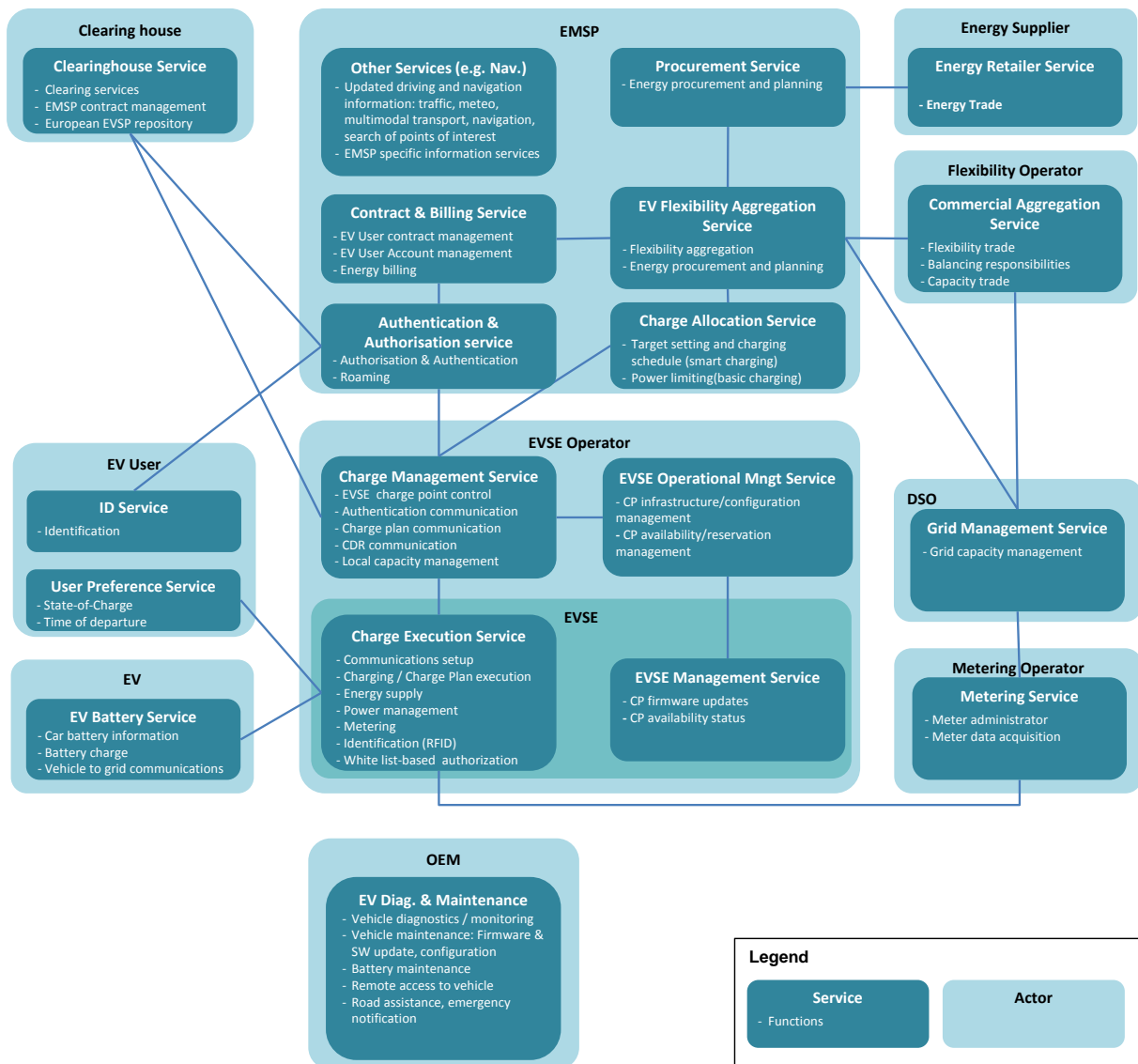


Figure 5: Example of mapping services on actors in the EV ecosystem

Figure 5 shows a logical mapping of services, but other mappings can be thought of too, such as an EVSE Operator providing the Charge Allocation Service, instead of the EMSP. In this case the EMSP has a lesser role, while the interfaces among the services stay the same as shown in the figure below. Similarly, in all cases of mapping of services to actors, the interfaces between the services remain the same.

Flexibility services are assigned to the EV Flexibility Aggregation Service and the Commercial Aggregation Service (aggregating flexibility from other domains too). The latter is in this figure mapped to the Flexibility Operator (i.e. a separate actor), but other mappings are also possible, such as an Energy Supplier providing these services and becoming an Energy Service Provider. Other logical actors that can provide this service are the EMSP or the EVSE Operator.

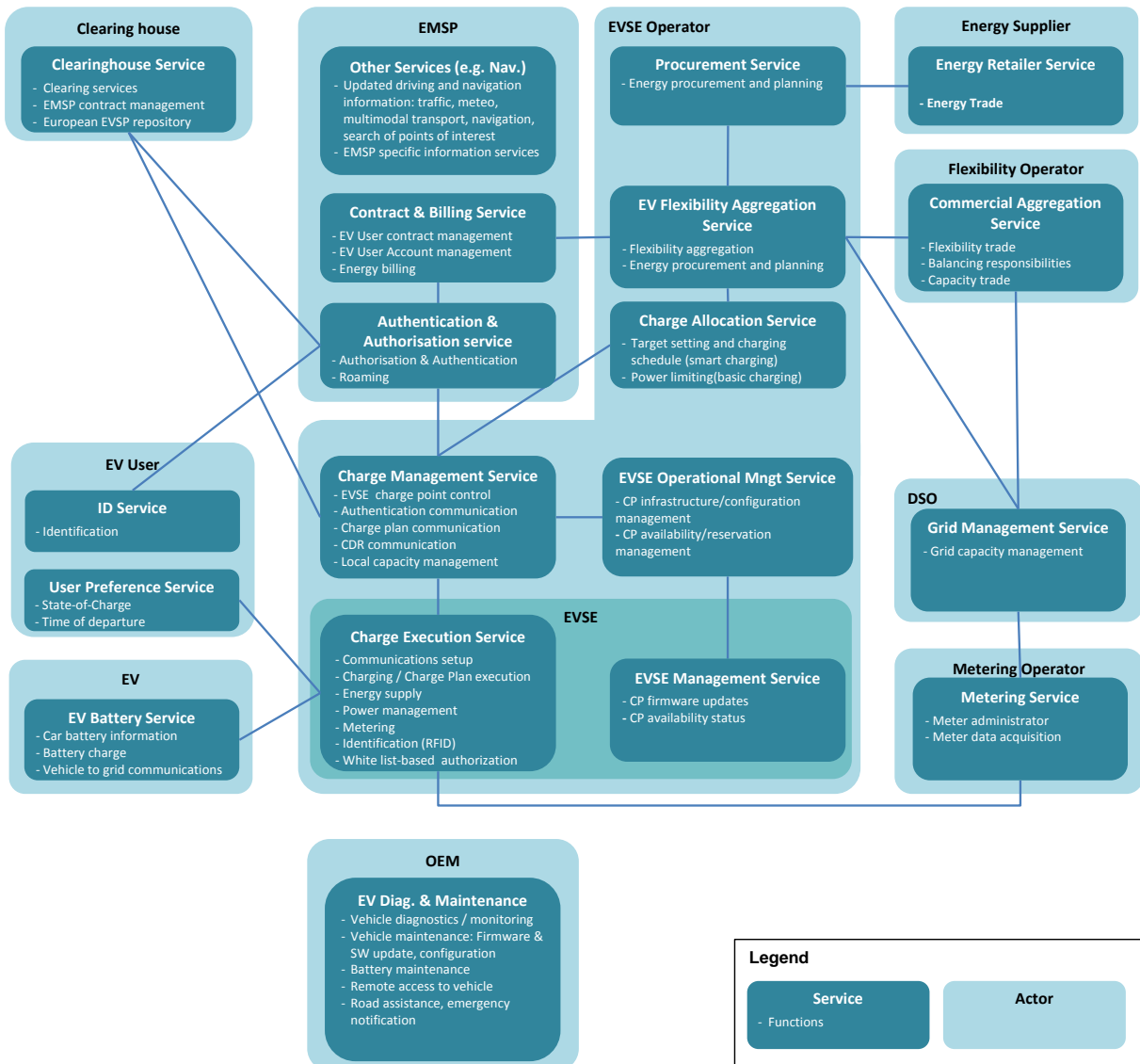


Figure 6: This mapping of services to actors shows an EVSE Operator providing smart charging services



3. COTEVOS Basic Reference Architecture

This chapter introduces the e-mobility basic reference architecture. Following this we develop interface reference architectures which describe the COTEVOS basic reference architecture from four viewpoints: the EV-EVSE physical interface viewpoint, the charging infrastructure viewpoint, the EMSP interfaces viewpoint, and the metering viewpoint. It also describes which information is exchanged between actors and as such describes the information layer of SGAM.

3.1. Basic Reference Architecture

When looking a bit wider than the EV system itself, the smart grid architecture is relevant to look at, specifically architectures supporting use cases for Demand-Response and Demand Side Management functionality. In these use cases a grid actor (e.g. Energy Supplier/Flexibility Operator) sends control and price signals to Grid users (e.g. Smart Homes, Smart Buildings and Industrial Facilities) in order to involve them in providing energy services (flexibility) for grid operation. Implementing the same technical solution used for interfacing the Grid Users to the Energy Supplier/Flexibility Operator (e.g. OpenADR), the EV ecosystem could also be a provider of energy services to the grid.

A similar control interface is also needed for grid-stable charging of EVs (especially at a large scale). Currently, these domains (Smart Homes, Smart Buildings and EVs) are not connected, although they all deal with flexibility from production or consumption of electricity. Since developing and standardizing different interfaces for the same function is not preferable, a few interfaces in the EV domain that seem logical need to follow a different path. Therefore the actor DSO/Grid Operator is exchangeable with a Smart Grid Management actor. This actor will likely create and maintain a Smart Grid Management System from a grid point-of-view, which will be the actual system that other domains (among them the systems of electro-mobility actors, the smart building and smart houses) will interface with regarding grid load and available capacity. Typically this actor would be performed by a DSO party.

Besides technical flexibility (grid-based), commercial flexibility (market-based) can be implemented by the EMSP or EVSE Operator (depending on the mapping mentioned above) which interfaces with the Flexibility Operator as the Balance Responsible Party to use the available flexibility of the EVs to reduce imbalance between planned production/consumption.

The figure below describes the basic reference architecture for COTEVOS.

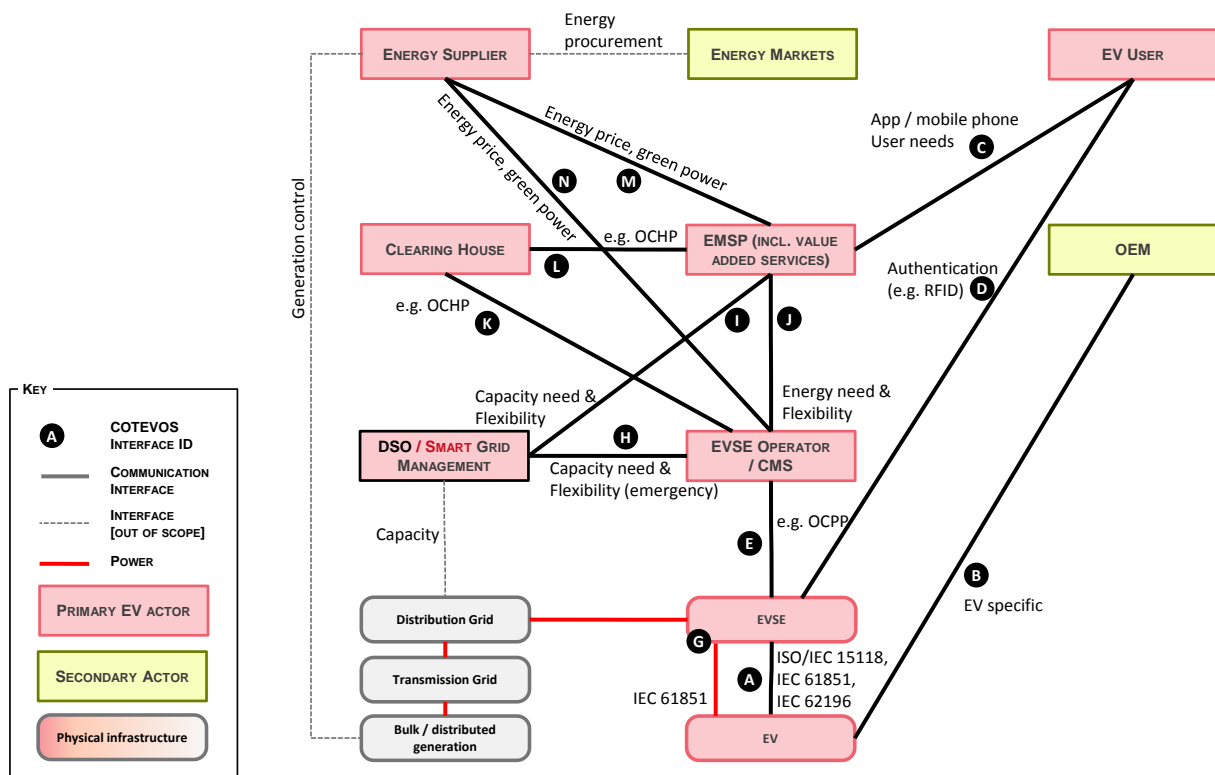


Figure 7: COTEVOS basic reference architecture

The figure distinguishes between primary and secondary actors⁴. A secondary actor is an actor involved indirectly in the charging session. For example the Energy Market is required for proper functioning of the energy system but its interfaces are already in place and out of scope of the COTEVOS project. This also holds for the OEM, as its interface is EV specific and usually proprietary (and might contain more services).

The figure also shows the physical infrastructure (at the bottom of the figure) that is needed to charge the car. The grey entities and dotted-grey relations are out of scope of COTEVOS.

The actors have been verified with views and architectures from M/468, eMI3, and Green eMotion (see Green eMotion deliverable D7.6 chapter 8, <http://www.greenemotion-project.eu/dissemination/deliverables-standards.php>) and although there are differences, the architecture above has fit these architectures very well and has also been verified to be future proof (w.r.t. integration of Smart Home and Building beside only Smart Charging EVs).

3.2. Interface reference architectures

To analyse the interfaces present in the basic reference architecture, the architecture is sliced in four areas, each addressing a different viewpoint. The viewpoints are based on different focus areas with different expertise:

- Physical viewpoint addresses the physical interface between the EV and the EVSE. Protocols and standards regarding the plugs, charge modes, EMC, etc. are part of this viewpoint.

⁴ Here to distinguish between the COTEVOS definition of »primary« and »secondary actor« and the definition in ISO/IEC 15118 standard. ISO/IEC 15118 is mostly focused to EV, EV user and EVSE and consequently only these actors are defined as »primary«. COTEVOS has a much wider scope and therefore also the list of primary actors is more extended.



- Physical + EVSE Operator viewpoint addresses the interface between the EV / EVSE and the backend systems of the EVSE operator.
- EMSP interfaces viewpoint addresses interfaces of the systems that implement roaming, basic or smart charging. This includes the actors DSO, EMSP, EVSE Operator, Energy Supplier, and Clearing House.
- Metering viewpoint addresses the interfaces needed for metering.

Each of the viewpoints are drawn in Figure 8 and described in detail in the following sections.

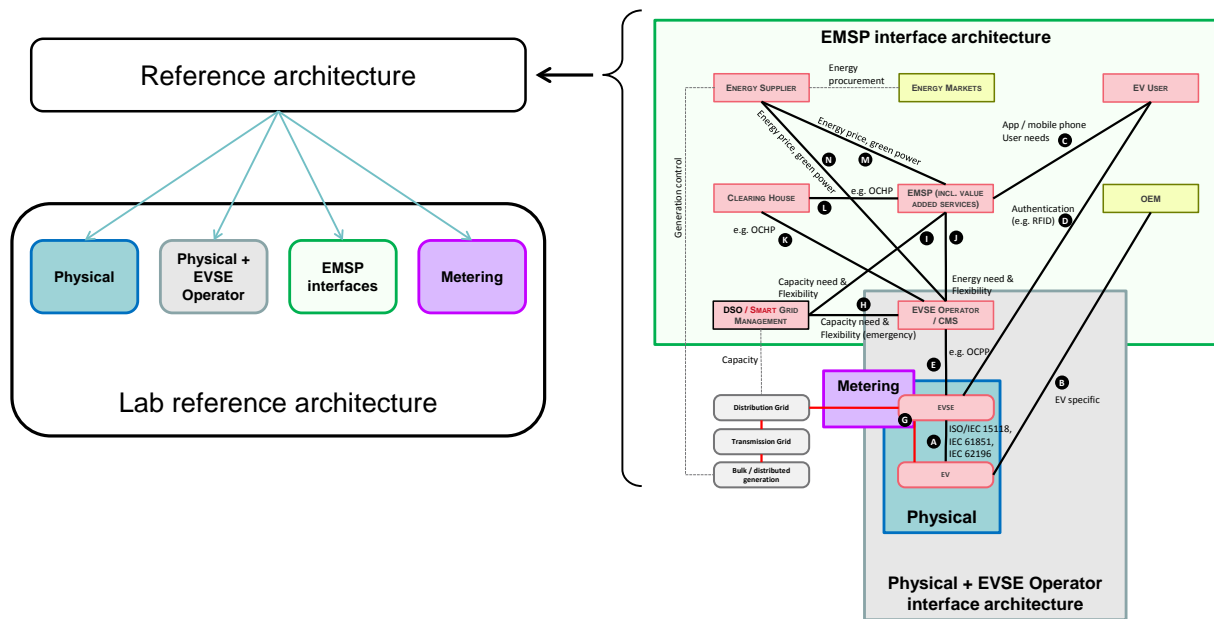


Figure 8: Lab reference architecture divided into four different viewpoints.

3.2.1. EV – EVSE Physical interface reference architecture

This section describes the interface reference architecture focusing on the physical interoperability of the actors in the reference architecture, thereby focussing on their interfaces (e.g. ISO/IEC 15118, IEC 61851, IEC 62196). This section also includes the (physical part of the) identification of the EV user.

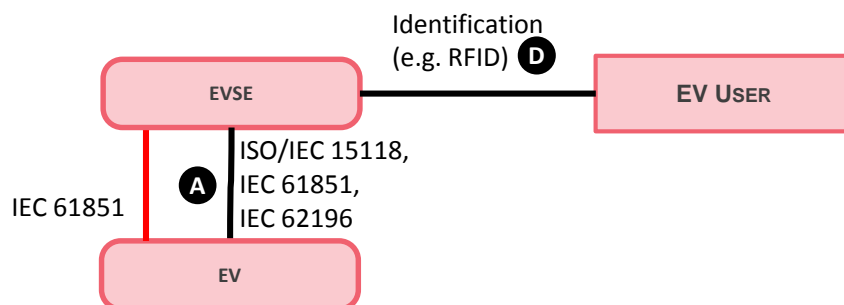


Figure 9: Physical actors and their interfaces



ID	Actor 1	Actor 2	Short description	Possible protocols standards /	Remarks
A (communication)	EV	EVSE	Exchange of information required for the actual charging session	ISO/IEC 15118	ISO/IEC 15118 must enable charging according to IEC 61851 if the actor on the other side of interface doesn't support ISO/IEC 15118
			Exchange of information to provide safety functionality for charging	IEC 61851, CHAdeMO	
A (physical connection)	EV	EVSE	Means to establish conductive path between EVSE and EV	Standards: IEC 62196, CHAdeMO	
D	EV user	EVSE	Identification of EV user at EVSE ⁵	ISO/IEC 14443, Calypso	Most common chips: MIFARE

Table 2: Summarised overview of the interfaces for physical interoperability

Types of connections of EV to EVSE (IEC 61851-1:2010 section 6.3.1; IEC 61851-1 ed.3 draft 11.7.2014 sections 3.1.12 – 3.1.14):

- Case “A”: supply cable and plug permanently attached to the EV
- Case “B”: cable assembly detachable at both ends
- Case “C”: supply cable and vehicle connector permanently attached to the charging station

Charging modes⁶ (IEC 61851-1:2010 section 6.2; IEC 61851-1 ed.3 draft 11.7.2014 sections 3.1.8 – 3.1.11 and 6.2):

- Mode 1:
 - connection of the EV to the a.c. supply network (mains) utilizing a cable and plug, that is not fitted with any supplementary pilot or auxiliary contacts, and connects to a standard socket-outlet
 - AC charging, single or three-phase
 - max current 16 A per phase
- Mode 2:
 - connection of the EV to the a.c. supply network (mains) utilizing a cable and plug connected to a standard socket-outlet, with a control pilot function and system for personal protection against electric shock placed between the EV and the socket outlet
 - AC charging, single or three-phase
 - max current 32 A per phase
- Mode 3:
 - connection of the EV utilizing EV supply equipment permanently connected to the a.c. supply network (mains), and where the control pilot function extends to control equipment in the EVSE
 - AC charging, single or three-phase
 - max current 70 A for single-phase or 63 A per phase for three-phase charging
- Mode 4:

⁵ Pay-As-You-Go methods (payment at EVSE - coin machine, credit cards or at counter, etc.) are outside of the scope of the COTEVOS project.

⁶ For details refer to D3.1, section 9.1



- connection of the EV to the a.c or d.c. supply network utilizing a d.c. EVSE or DC EV charging station using a control pilot function
- DC charging
- Voltage not exceeding 1500V d.c with max current 400 A
- Work environment between -30° to 50°C

Vehicle connectors, plugs and socket-outlets⁷ (IEC 62196-1:2014; IEC 62196-2:2011; IEC 62196-2 ed.2 draft 8.8.2014; IEC 62196-3:2014):

- AC charging (IEC 62196-1, 2 & 3):
 - Type 1 (SAE J1772 “Yazaki”)
 - Type 2 (VDE-AR-E 2623-2-2 “Mennekes”)^{8,9}
 - Type 2 Combo^{8,9}
 - Type 3 (“EV Plug Alliance”)
- DC charging (IEC 62196-1 and 3):
 - Type 2 Combo^{8,9}
 - CHAdeMO

Communication – physical and data link layers¹⁰:

- AC charging:
 - low level communication: IEC 61851 (part 18)⁸
 - high level communication: ISO/IEC 15118-3 (PLC - IEEE 1901 Profile Green PHY on CPLT/PE)⁸
- DC charging:
 - IEC 61851- (parts 23 &24)⁸
 - ISO/IEC 15118-3 (PLC - IEEE 1901 Profile Green PHY on CPLT/PE)⁸
 - CHAdeMO

3.2.1.1 Required data to be exchanged

3.2.1.1.1 Interface A: EV – EVSE

The required information exchange is defined in the following standards:

- AC charging:
 - IEC 61851 (part 1)⁸
 - ISO/IEC 15118 (part 2)⁸
- DC charging:
 - IEC 61851 (parts 23 and 24)⁸
 - ISO/IEC 15118 (part 2)⁸
 - CHAdeMO

Communication according to IEC 61851 standard is a low level communication and defines the exchange of the following information¹¹:

- AC charging:
 - EVSE and EV correctly connected: via proximity pin
 - maximum cable assembly current (applicable for connections Case “A” and Case “B”): via proximity pin and resistor in cable assembly
 - maximum available current: via PWM signal (duty cycle) on control pilot
 - correct earthing
 - EV ready to charge: via voltage level on control pilot
 - ventilation requirements during charging (optional): via voltage level on control pilot

Communication according to IEC 61851 parts 23 and 24 standard is a low and high level communication and defines the exchange of the following information:

⁷ For details refer to D1.1 [1], section 2.3.3.1

⁸ Preferred by ACEA (see [6])

⁹ Preferred by EU (see [7])

¹⁰ For details refer to D3.1 , sections 9.1 and 10.1

¹¹ For details refer to D1.1 [1], section 8.5.4



- DC charging:
 - EVSE (cable assembly) mated
 - Correct earthing
 - Max cable current
 - Charge request
 - Flooded or sealed battery
 - Requested voltage and DC current (mode 4)

Communication according to ISO/IEC 15118 standard is a high level communication and defines the exchange of information for the following function groups¹²:

- start of charging process
- communication setup
- certificate handling
- EV identification and authorization
- value added service
- end of charging
- target setting and charging scheduling
- charging control and re-scheduling

Communication according to CHAdeMO is specified by the CHAdeMO Association. The CHAdeMO Association provides its own compliancy regime. Only CHAdeMO authorized parties are allowed to provide CHAdeMO seals for EVSEs and EVs. In such closed regime there is no or little added value for initiatives like the COTEVOS project. Therefore the CHAdeMO standard will not be considered in the remainder of this document.

3.2.1.1.2 Interface D: EV user to EVSE (at EVSE)

For identification of the EV user, different methods are available. As concerns the interoperability, only the identification with RFID cards and by SMS or smartphone app is relevant. Other methods (e.g. using credit cards) typically use well defined standard methods for data exchange, verification and validation and follow, after a payment session has been successfully completed, the same information route as the identification with RFID cards. This is the reason why these other methods are not explicitly addressed within the scope of COTEVOS.

The world-wide unique EV user identifier is the precondition for correct recognition of EV user in the processes of charging spot reservation, charging authorization and billing of charging service. Examples of world-wide unique EV user identifier are:

- EV user's phone number: for identification with SMS
- RFID card serial number stored in block 0, section 0 of RFID card
- EV user contract number which is composed of EV user contract ID (defined by EV user's EMSP) and of identification number of EV user's EMSP

For identification by using smartphone or sending SMS the interface physical layer is defined by standards relevant for mobile communications. Identification with RFID cards is based on standard ISO/IEC 14443.

The data necessary to be exchanged between the EV user and the EVSE (or EVSE Operator in the case of identification with phone – SMS or app) is:

- identification with SMS (EV user identifier is represented by the phone number):
 - EVSE ID number
 - charging spot ID code
- identification with smartphone app:
 - EV user identifier: phone number or contract number
 - EVSE ID number
 - charging spot ID code

¹² For details refer to D1.1, section 8.5.5



- the list of exchanged data may be extended with information relevant to scheduling the charging (i.e. time available for charging, required energy, maximum current of EV battery charger, if the user allows variation of charging load or requires forced charging)
- identification with RFID card (EVSE ID number is assigned by the EVSE when forwarding charging request to EVSEO back-end; charging spot ID code is determined when the EV user plugs the cable assembly plug into the one of available socket-outlets on the EVSE):
 - EV user identifier: EV user contract number or RFID card serial number

3.2.2. EV – EVSE Operator backend and OEM

This section describes the interface reference architecture where interoperability regarding physical interfaces and information interfaces meet, focussing on the interoperability of the information required in the system.

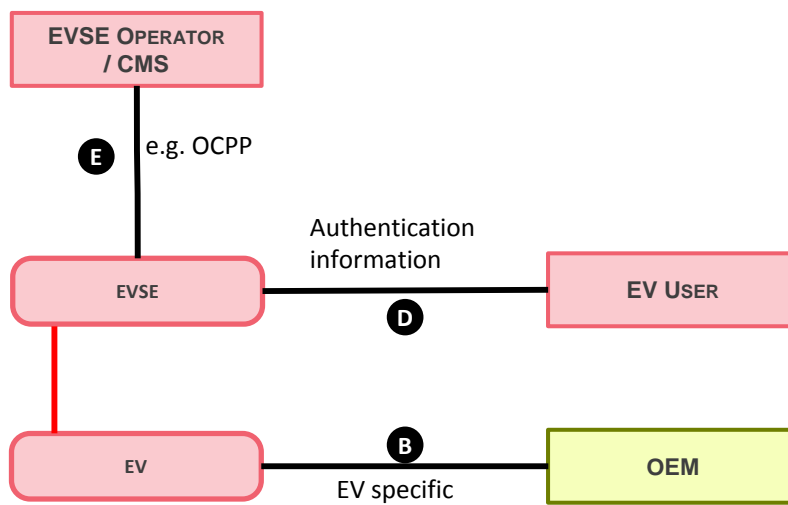


Figure 10: The interfaces and actors where physical interoperability and information interoperability meet

Table 3: Summarised overview of the interfaces



ID	Actor 1	Actor 2	Description	Possible protocols	Remarks
B	OEM	EV	User (charging) preferences	Proprietary and specific for the type of EV	via EV on-board information system
			Maintenance management	Proprietary and specific for the type of EV	
			On-board services	Proprietary and specific for the type of EV	
C	EV User	EV	User preferences	Proprietary and specific for the type of EV	
			Maintenance management	Proprietary and specific for the type of EV	
			On-board services (provided by OEM or internal to EV)	Proprietary and specific for the type of EV	
			Identification information	RFID	
D	EV User	EVSE	EVSE reservation	OCPP	
E	EVSEO	EVSE	Configuration	OCPP	

3.2.2.1 Required data to be exchanged

3.2.2.1.1 Interface B: OEM – EV

The interface between the EV – EVSE backend and the OEM is currently not standardised, and cannot be expected to be standardised in the future. This interface is within the domain of the OEMs and as such uses proprietary specific protocols. The COTEVOS Deliverable 3.1 holds a more detailed discussion about this interface B.

The data that will be exchanged between the EV and the OEM will depend on the OEM and his specific needs. Possible data would be:

- Exchange of User preferences (basic information elements)
- Exchange of information related to maintenance (remainders, dates, FW/SW request and confirmation)
- Exchange of on-board service information (EV diagnostics, Battery status, OEM specific services)

At the moment of writing, at least some car manufacturers are reading and evaluating huge amounts of data which they collect during standard service inspections. This data is thereafter used for OEM internal evaluations. It is expected that OEMs will not change their behaviour of data collection although the interface they will be using is unclear at the moment. Being an electric vehicle or a conventional car the OEM will provide service intervals at which the car needs to be inspected. These service inspections will be used for data collection regardless of the car being an EV or not. In this context it remains unclear if OEMs would adapt to standardization if such would exist.

This area of the interface architecture is believed not to affect the mobility of EV users in case of interoperability issues, and will therefore be left outside the scope of the COTEVOS project.

3.2.2.1.2 Interface C: EV User – EV

The interface between the EV user and the EV has no specific standard and uses proprietary specific protocols. The data necessary to be exchanged is:

- Exchange of User preferences regarding (basic information elements)
 - At least its desired state-of-charge, and possibly the desired departure time



- Exchange of other information (out of scope of COTEVOS), such as:
 - information related to maintenance (remainders, dates, FW/SW request and confirmation)
 - on-board service information (EV diagnostics, Battery status, OEM specific services)
 - information for setting internal conditions (e.g. temperature)

3.2.2.1.3 Interface D: EV User – EVSE

The interface between the EV user and the EVSE has no specific standard and uses proprietary specific protocols. The data necessary to be exchanged is:

- Exchange of Identification information (e.g. RFID, for authentication and authorisation purposes).

3.2.2.1.4 Interface E: EVSE0 – EVSE

The data necessary to be exchanged is:

- Exchange information for EVSE reservation:
 - EVSE status/availability
 - Reservation (User ID number, EVSE ID number, ReservationId (optional), Date and time) and cancelation commands
- Exchange information for EVSE Configuration:
 - Monitoring (status/availability, diagnosis, metering measures)
 - Control (authorization of charging, commands for start/stop charge process, settings)
 - Maintenance (commands for FW/SW update)

Basically, the OCPP protocol covers these needs. For a detailed analysis, please refer to section 11.2 of D3.1.

3.2.3. EMSP interfaces

This section describes the interface reference architecture regarding all interfaces around the EMSP. The interoperability challenge here is related to interoperability at communication and information layer rather than component layer.

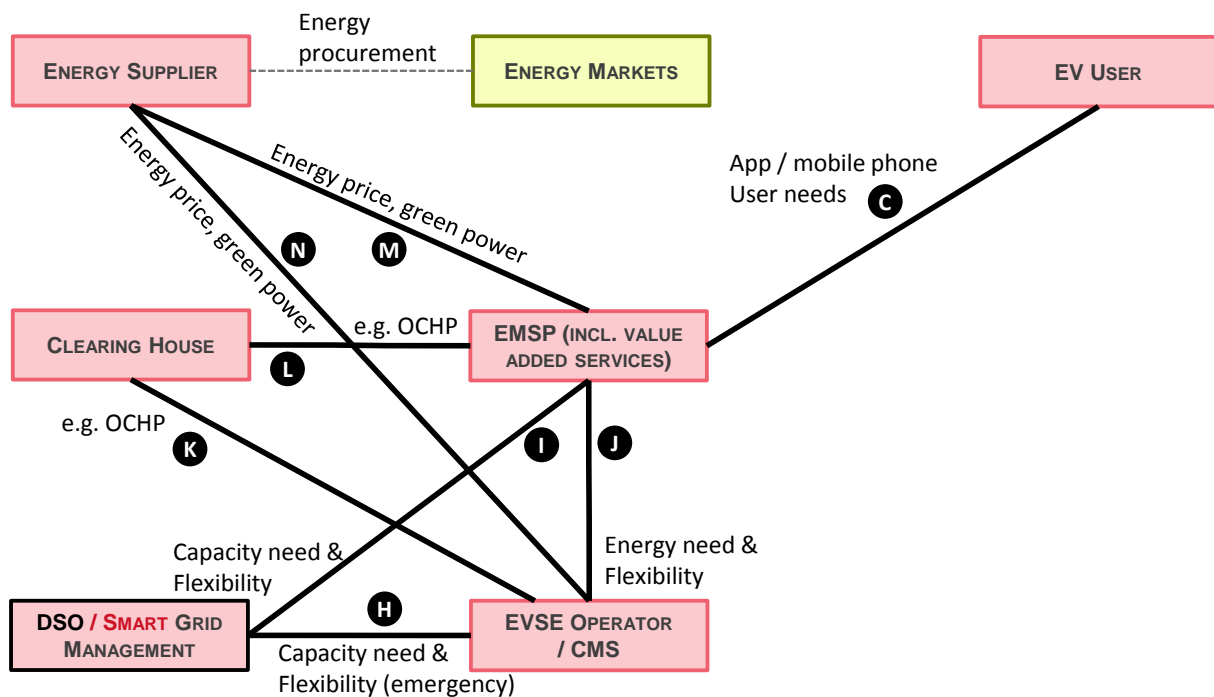


Figure 11: Interfaces and actors around the EMSP

Table 4: Summarised overview of the interfaces of the EMSP

ID	Actor 1	Actor 2	Description	Possible protocols	Remarks
C	EV User	EMSP	User preferences (e.g. State-of-Charge, Time of departure).	EMSP specific, proprietary	EV User will get a specific app from the EMSP for this purpose
H	EVSEO	DSO/Smart Grid management	Capacity information required for charging one or more EVs, Grid capacity that is available, amount of flexibility the EVs can offer (based on SoC and ToD)	OSCP (Open Smart Charging Protocol, in part). OpenADR	Seems to be a gap, no real standards available
I	EMSP	DSO/Smart Grid management	Same as interface H	Same as interface H	Same as H
J	EVSEO	EMSP	Enable roaming between different EMSPs and EVSEOs (bilateral agreement), Smart charge plans in case of EMSP doing smart charging.	Point-to-point proprietary protocol	Seems to be a gap when EVSEO and EMSP are separate parties.
K	EVSEO	CH	Enable roaming of clients (EV users) of different EMSPs	OCHP	Open protocol see http://ochp.eu . Provides also a definition of IDs for customers and charge points. Alternative is DIN SPEC 91286
L	EMSP	CH	Enable roaming on EVSE of different EVSEOs	OCHP	See K
M	EMSP	Energy Supplier	Power type (green, grey, ...), power price	Gap	No standard available here for Smart Grid operation



N	EVSEO	Energy Supplier	Same as interface M	Gap	No standard available here for Smart Grid operation
-	EV	EMSP (Fleet Manager)	Enable fleet tracking	Point-to-point proprietary protocol	Out of scope of COTEVOS
-	EV	EMSP (Emergency Operator)	Enable emergency notifications	Point-to-point proprietary protocol	Out of scope of COTEVOS

3.2.3.1 Required data to be exchanged

From the perspective of roaming service, different scenarios can be identified: bilateral agreement (EVSEO, EMSP), roaming involving an external entity, the clearing house, through a market place or between different clearing house operators. The next points summarize the underlying information exchanges, for details see Section 9.6.1 Interface F: Roaming Scenario of D3.1.

3.2.3.1.1 Interface C: EV User – EMSP

- User preferences, at least required for smart charging is the State of charge of the battery or Range / energy demand and the Time of Departure.
- In case of smart charging with financial incentives: proposals and offer for charging, available budget, Energy type preferences (RES), consent (or not) of EV user to allow smart charging (variation of charging load below the max. power).
- This interface also provides access to the services offered by the EMSP: Reserve, navigation, charge point search, charge point availability and so on. Each service defines its own information exchange needs.

3.2.3.1.2 Interface H: EVSE Operator – DSO/Smart Grid management

- Grid capacity information that is required for charging one or more EVs, which allows the DSO to check if it can accommodate the charging.
- The DSO can provide the current grid capacity that is available
- The EVSE Operator or EMSP can provide the amount of flexibility it can offer for the EVs it services in a certain part of the grid (based on SoC and ToD of each of the EVs and their location based on EVSE identification)
- In some case also charge plans need to be exchanged

OSCP (Open Smart Charging Protocol) is the currently available protocol that supports this interface in part.

3.2.3.1.3 Interface I: EMSP – DSO/Smart Grid management

- Identical to interface H.

3.2.3.1.4 Interface J: EVSEO – EMSP

- Exchange of Authorisation Data (basic information elements (User ID, EVSE Id, profile as response), details in D3.3)
- Exchange of Charge Data, the raw billing data (Charge Detail Records)

In bilateral agreements the following information can be exchanged:

- Exchange of Charge Point Information (Static POI data, ChargePointInfo (status, availability))
- Exchange for reservation (reserve information /cancelation)

3.2.3.1.5 Interface K: EVSEO – CH

- Exchange of Authorisation Data (basic information elements, details in D3.3)



- Exchange of Charge Data, the raw billing data (Charge Detail Records: Transaction ID, time, date, Power, Energy)

In bilateral agreements the following information can be exchanged:

- Exchange of Charge Point Information (Static POI data, ChargePointInfo (status, availability))

3.2.3.1.6 Interface L: EMSP – CH

- Exchange of Authorisation Data (basic information elements, details in D3.3)
- Exchange of Charge Data, the raw billing data (Charge Detail Records)
- Exchange of Charge Point Information (Static POI data, ChargePointInfo (status, availability))
- Exchange for reservation (reserve information /cancelation).

OCHP covers most of the functionalities identified; however, only covers a common roaming scenario, being restricted to charge and exchange of Charge Point Information (static and live) (other services as reservation, monitoring are out of the scope).

3.2.3.1.7 Interface M: EMSP – Energy Supplier

- Information regarding the type of energy (green, grey) and the price (can be a Time of Use) and availability of this energy.
- In case the Energy Supplier also has an “Energy Services Supplier” role (e.g. Flexibility Operator), the protocol used to interface this actor with EMSP could be OpenADR.

3.2.3.1.8 Interface N: EVSE Operator – Energy Supplier

- Identical to interface M.

3.2.3.1.9 EV - EMSP (Fleet Operator, Emergency Operator)

This interface is out of scope for the COTEVOS project and is proprietary.

- Exchange of Emergency information (emergency and vehicle data)
- Exchange of fleet information (tracking data: SoC, position, fleet management service data: route calculation, charging history, V2G info, consumption)

Interaction details are described on Section 9.2 Interface B of D3.1.

3.2.4. Metering

This section describes the metering interface reference architecture, with a focus on interfaces of G: metering.

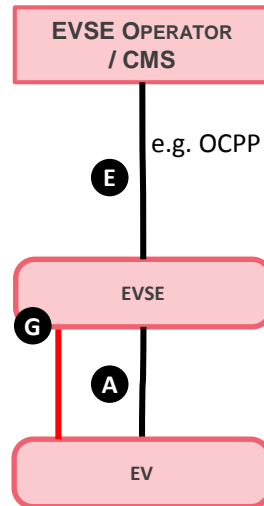


Figure 12: The interfaces and actors directly related to metering

ID	Actor 1	Actor 2	Description	Possible protocols	Remarks
G	EVSE	Meter Operator	Metering data sent to the meter operator. Depending on the country's legislation, this can be the DSO (to calculate e.g. transportation costs) or the Energy Supplier (for sending bills purposes to the EMSP/EVSE Operator).	Manual read-out, EN 62056, EN 13757-1:2002, IEC 61968-9.	Depends on country/legislation (see below)
A	EV	EVSE	Metering data	ISO/IEC 15118 (optional)	
E	EVSE	EVSE Operator	Metering data	OCPP	

Table 5: Summarised overview of the metering interfaces

In standard EVSEs for AC charging metering is not seen as an issue. Further there is no interoperability issue in that case since the meter needs to fulfil country's legislation.

For that reason test cases for metering are not of the highest importance for COTEVOS, so we will focus on other interfaces and interoperability topics first.

Still we want to ensure that metering and its interfaces are embedded in the COTEVOS lab architecture. In several labs we can measure the power (quality) and energy provided to the EVSE and the EV. Using meter readings we can verify the overall system performance and efficiency on this topic.

Regarding DC charging, metering is a more complicated topic, and when in future other options become possible metering test cases will become necessary. These future options range from one meter for a pool of EVSEs, doing the metering possibly at the EV side. V2G scenarios require also more regarding metering: not only energy but also power needs to be measured.

3.2.4.1 Required data to be exchanged

3.2.4.1.1 Interface G: EVSE - EV

The interface between the Energy Meter and the Meter Operator, as depicted in the COTEVOS DoW does not exist as such for most of the European countries. Generally, the energy meter is operated and owned by the DSO when assuming the role of the Meter Operator. The handling and management of meter data is directly to be controlled by the DSO [8]. Due to the fact that the DSOs



are responsible for the future implementation of smart meters it cannot be expected that the DSOs will in foreseeable future not be owner and operator of the Energy Meter.

The physical connection of the energy meter is regulated within the national grid connection codes. These regulations are national and specific for each country even though they are partly overlapping. The Meter data will be provided from the meter operator/owner to the Energy Supplier/retailer if the customer gives his permission to do so. This permission can be seen as obligatory as it is necessary for the billing process.

The national grid connection codes define a frame under which any customer is allowed to connect to the distribution grid at a point of connection where the DSO provides an energy metering infrastructure. If there are measurements executed within the EV or the EVSE they cannot be expected to be accepted by the DSO or the Energy Supplier as they have their own measurement infrastructure which is under their total control and thus will be seen as superior from their point of view. If there does not arise a specific benefit for the Energy Supplier to use alternative measurements than those provided by the DSO a change for the status of this interface cannot be expected.

3.2.4.1.2 Interface A: EV - EVSE

The IEC 61851 standard doesn't allow any exchange of information between the EV and EVSE related metering information.

The exchange of metering information in ISO/IEC 15118 is optional and requires the application of security procedures (signature and encryption of messages, Contract Signing Key / Certificate). The meter reading info is cyclically sent by EVSE to EV. The EV confirms the meter readings and thus provides the basis for billing the charging service.

3.2.4.1.3 Interface E: EVSE – EVSE Operator

Metering data sent from the EVSE to the EVSE Operator by means of OCPP. This information is used to create bills for the EV User, describing the amount of energy used for charging the EV.

4. Lab reference architecture

In this chapter we describe the envisioned architectures from the task partners (AIT, TNO, RSE, TECNALIA). These are combined to form a COVETOS lab architecture which is described in detail. Following this an analysis of the commonalities and gaps in actors and test cases between task partners is presented.

4.1. Envisioned architectures

4.1.1. AIT

The AIT lab architecture is based on a co-simulation environment, where multiple simulators for different domains work together to fulfil an overall simulation of the electric distribution grid and the usage of electric vehicles with their specific charging processes. This co-simulation environment is enhanced by a hardware-in-the-loop support for EV charging stations. Figure 13 presents this configuration setup.

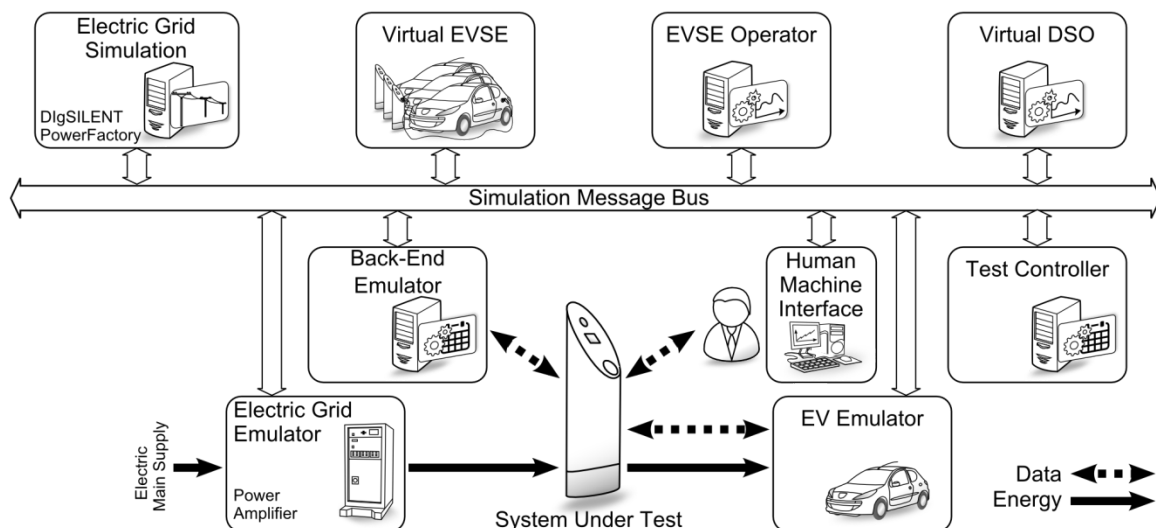


Figure 13: AIT lab architecture

4.1.1.1 General description

The architecture of the test system is based around a real-world charging station as Device under Test. An **electric grid emulator** is used to generate the necessary main supply for testing the charging station. Therefore a 4-quadrant power amplifier is used. The test data for setting this amplifier are generated by the **electric grid simulator**. Thereby a model of an electric distribution grid is used to generate the test data of the impact of the present charging processes.

The output of a charging station is connected to an **EV-Emulator**, which implements a variable current sink with a deposited model of a battery charging cycle. The described components are used to influence the electric path of a charging station. Another function of the EV-emulator is the communication over the EVSE-EV data interface. Therefore different protocols (IEC61851-1, ISO15118) can be established for this communication.

For controlling the charging station from a back-end system or EVSE operator another **gateway component** is necessary. Applied protocols are the Open Charge Point Protocol or similar ones in future applications.

For the complete simulation of a charging system some components are also necessary. Therefore additional **virtual charging stations** are used to increase the system load of the EVs in the simulated electric grid. For future smart charging applications an additional **EVSE operator** will timely coordinate

the charging processes to fulfil the electric grid requirements. As last component a test controller is available to manage the correct activity of the whole environment.

The communication within this architecture is based on the Simulation Message Bus. This system transmits data as text messages between all available components. The Simulation Message Bus also synchronizes the simulation components for correct and parallel execution.

The reference architecture of the lab focuses on the functionality of testing charging stations for electric vehicles. Therefore all interfaces of a dedicated charging station or system are controlled by special designed mock-up or back-end components. The mock-up interfaces don't provide any functionality for the generation of simulated test data. They only allow the access to the commonly used EVSE protocols. Therefore these components work as protocol converters between the subsequently described test controller and the charging station.

The main component of the architecture is the test controller. This controller provides the necessary test data, which are stored in a database. This allows reproducible results for the different test cases. For fast and easy development of the test cases the system has an included script parser. The scripted test case invokes the functionality of the distributed mock-up components. Therefore it uses a text-based Remote Procedure Protocol, which is transported and exchanged over the Simulation Message Bus (already described in section 4.1.1.1). Figure 14 shows the internal architecture of the test controller.

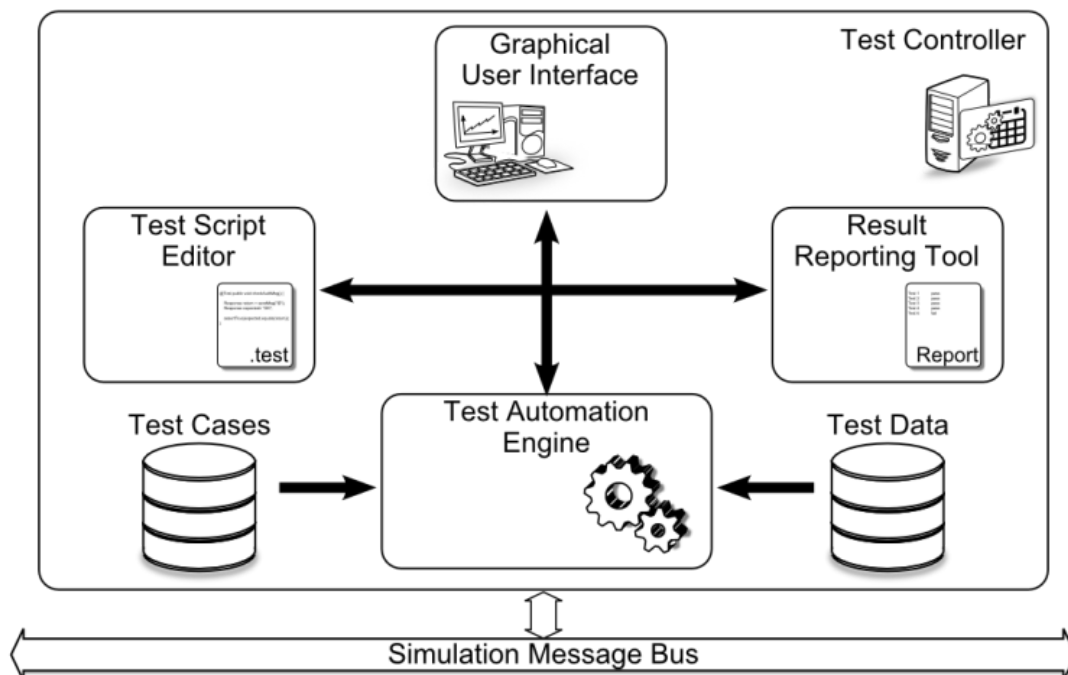


Figure 14: Internal architecture of the test controller

The test controller is able to execute and interpret the test cases automatically. Therefore an executed test can be verified, if it is passed or failed (like unit testing in software development).

This system is focused for the test purpose of charging stations for EVs. The universal and adaptable architecture as also the scripting functionality allows a fast modification to future needs of EV charging infrastructures.

4.1.1.2 Supported test cases

The following table lists the envisaged test cases, with their interface, standard, DUT (Device Under Test).



TEST CASE	INTERFACE	STANDARD	DUT	COMMENT
USE CASE: CHARGING				
Uncontrolled charging	A: EV-EVSE	IEC 61851	1-1 EV control electronics	
			2-1 EVSE	
Control of the states	A: EV-EVSE	IEC 61851	1-1 EV control electronics	
			2-1 EVSE	
Control of power (duty cycle)	A: EV-EVSE	IEC 61851	1-1 EV control electronics	
			2-1 EVSE	
Charging scheduling	A: EV-EVSE	IEC 61851	2-1 EVSE	
USE CASE: EV USER SERVICES				
EVSE monitoring	E: EVSE- EVSEO	OCPP	2-5 EVSE communication to EVSEO	Monitoring of EVSE operation and status
			5-1 EVSEO CC	
EVSE control	E: EVSE- EVSEO	OCPP	2-5 EVSE communication to EVSEO	
			5-1 EVSEO CC	
USE CASE: AUTHORIZATION AND VALIDATION				
Customer ID recognition	D: EV user-EVSE		2-1 EVSE	only RFID, no ISO/IEC 15118
	E: EVSE- EVSEO	OCPP	2-5 EVSE communication to EVSEO	
			5-1 EVSEO CC	
USE CASE: GRID INTERACTION				
EVSE – Grid Interaction	EVSE – Grid	national grid codes	EVSE	Measurement of voltage, current, phase, frequency, harmonics, spikes.
EV – Grid Interaction	EV - Grid		EV	

Table 6: AIT Test cases

4.1.2. TNO

4.1.2.1 TNO EV Smart Charging Simulator

The TNO EV Simulator is based on the service view presented in section 2.3 and is shown in the figure below.

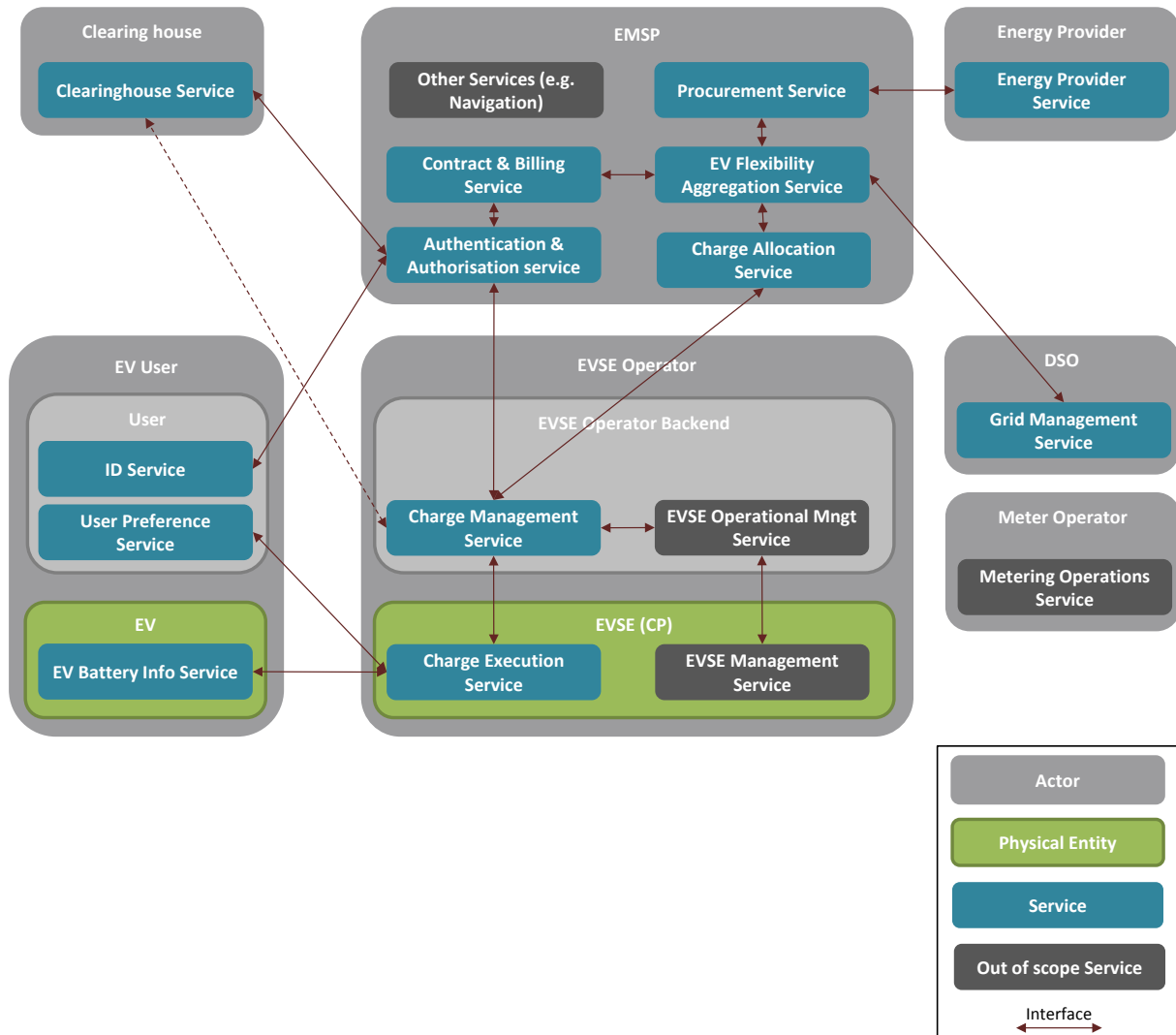


Figure 15: TNO EV Smart Charging Simulator

The main services needed for Smart Charging are implemented. Services that are not required for this use case are out of scope of the EV Smart Charging simulator (dark grey services). The TNO EV Simulator uses an Orchestrator component to start/stop and monitor all the services in the simulation and provides a Web-based GUI to configure, control and visualise the simulation and its results.

4.1.2.2 EV-IOP Lab-in-a-Suitcase general description

In the COTEVOS project EV systems and their interoperability with Smart Grids need to be tested. To be able to fully test the interoperability a full system approach is required. Such a full system cannot be built easily in a lab environment. It is too expensive, not all elements (of a Smart Grid) are available, or it is not even possible to create a real-life situation in a laboratory. Therefore TNO's approach is to perform interoperability tests from a system perspective by means of a system simulator.

In most other EV related projects, and also in this project, the start of system specification and design is often based on use cases. Also in this project this approach is taken and extended further by using the use cases as much as possible as a basis for test cases.

This means that the system simulation tool should be able to execute use cases (or at least parts of them). At the moment of writing this report, TNO has created an E-mobility System Simulation Tool, which contains instances of the different services of the different actors (from the E-mobility architecture). Also multiple actors of the same type can be present e.g. multiple EVs from different and

multiple EMSPs. These services exchange data, but not (yet) via specific standards/protocols, so the tool is in its current state a 'data focussed' E-mobility System Simulation Tool. In the remainder of the COTEVOS project it needs to be extended to a 'Protocol' E-mobility System Simulation Tool, where at least the EVSE Operator backend needs to be able to talk via a standardized protocol to the EVSE (likely the OCPP protocol) to be able to test a real EVSE. For the other interfaces it still needs to be defined what exactly will be required and/or feasible.

The picture below sketches the presumed context of the EV-IOP Lab-in-a-Suitcase, consisting of the mentioned E-mobility System Simulation Tool, an EV simulator box, smart cards, smart phones and cables.

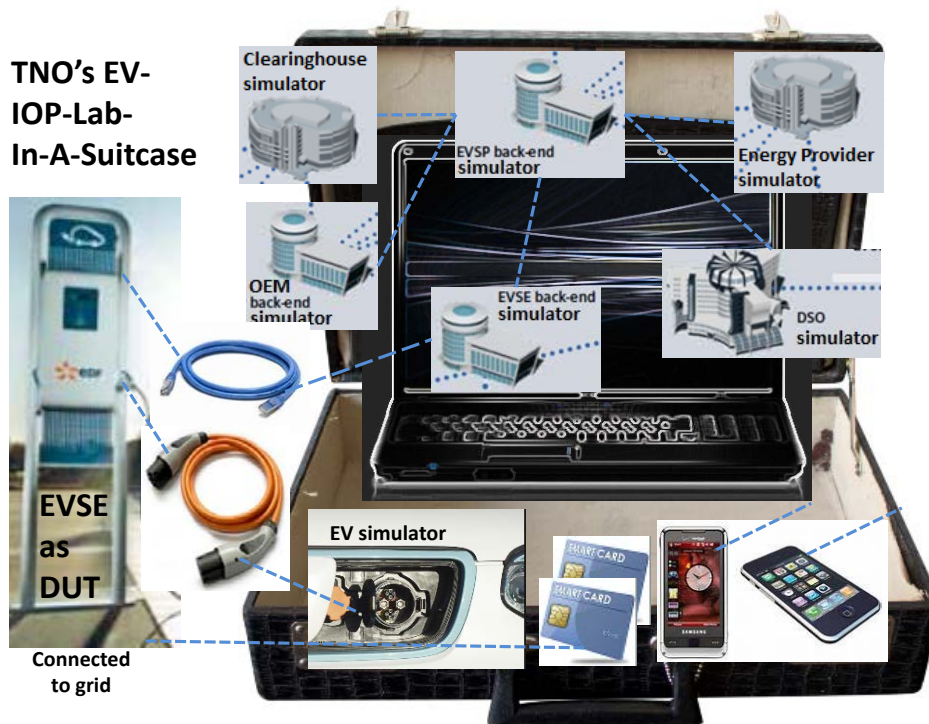


Figure 16: TNO's EV-IOP 'Lab in a Suitcase'

At the current stage, it is not completely clear how far the different simulation services can or will be worked out. Instead of simulation services another possibility is also to connect for example to real EMSPs and/or Clearing Houses to test their interoperability.

4.1.2.3 EV-IOP Lab-in-a-Suitcase envisioned supported test cases

TNO should be able with this EV-IOP Lab-in-a-Suitcase to test individual EVSEs and also EVSEs in combination with an EV. The exact definition of tests and round robin tests needs to be worked out in WP4. But it is expected to test 2-3 EVSEs (one from a TNO partner in the Netherlands, the other ones from or via consortia partners) and 1-2 EVs from consortia partners (or a HW unit that emulates a real EV).

The test cases to be performed are Smart charging and Authentication and Roaming, where possible based on the information from the following use cases:

- WGSP-1300 Smart (re- / de) charging
- WGSP-1400 Ensuring interoperability and settlement
- WGSP-1100 Uncontrolled charging

For this, expected interfaces/protocols/standards to be used are: ISO-IEC 15118, IEC 61851, IEC 62196, OCPP, and RFID.



TEST CASE	INTERFACE	STANDARD	DUT	COMMENT
USE CASE: CHARGING				
Uncontrolled charging	A: EV-EVSE	IEC 61851	1-1 EV	Functional interoperability test with emulated EV
			2-1 EVSE	
Control of the states	A: EV-EVSE	IEC 61851	1-1 EV	Functional interoperability test with emulated EV
			2-1 EVSE	
Control of power (static duty cycle per charge session)	A: EV-EVSE	IEC 61851	1-1 EV	Functional interoperability test with emulated EV
			2-1 EVSE	
Charging scheduling	A: EV-EVSE	IEC 61851	2-1 EVSE	
USE CASE: SMART CHARGING				
Initiation of charging process	A: EV-EVSE	IEC 15118	1-1 EV control electronics	
			2-1 EVSE	
EVSE-EMSP	proprietary	EVSE-EMSP	EVSE-EMSP	Smart Allocation service testing, information flow only
Termination of charging process	A: EV-EVSE	IEC 15118	1-1 EV control electronics	
			2-1 EVSE	
EVSE-EMSP	proprietary	EVSE-EMSP	EVSE-EMSP	Smart Allocation service testing, information flow only
Charging scheduling	A: EV-EVSE	IEC 15118, IEC 61851	1-1 EV control electronics	
			2-1 EVSE	
EVSE-EMSP	proprietary	EVSE-EMSP	EVSE-EMSP	Smart Allocation service testing, information flow only
Charging loop	A: EV-EVSE	IEC 15118, IEC 61851	1-1 EV control electronics	It is technically possible to dynamically control the maximum allowed current. This behaviour is however not supported by all EV brands.
			2-1 EVSE	
EVSE-EMSP	proprietary	EMSP smart charging	EMSP smart charging	Smart Allocation service testing, information flow only
Send charge details	E: EVSE - EVSE0	OCPP	EVSE-EVSE0	
	J: EVSE0 - EMSP	proprietary	EVSE0-EMSP	Information only
Handle grid constraints	I: DSO - EMSP	OSCP	EMSP EVSE0	Check if and how EMSP (and the rest of the system) reacts to capacity limiting by the DSO
	H: DSO - EVSE0			
USE CASE: EV USER SERVICES				
Charging	E: EVSE-	OCPP	2-5 EVSE	



TEST CASE	INTERFACE	STANDARD	DUT	COMMENT
Authorization	EVSEO		communication EVSEO to 5-1 EVSEO CC	
USE CASE: AUTHORIZATION AND VALIDATION				
Customer recognition	D: EV user-EVSE	RFID	2-1 EVSE	only RFID, no ISO/IEC 15118
	E: EVSE-EVSEO	OCPP	2-5 EVSE communication to EVSEO 5-1 EVSEO CC	
	J: EVSE-EMSP		EVSEO-EMSP	Information flow only
USE CASE: ROAMING SERVICES				
Customer recognition	L: CH-EMSP	OCHP	5-3 EVSEO-EMSP	
	K: EVSEO-CH	OCHP	9-1 CH Back	
Exchange information	K: EVSEO-CH	OCHP	5-3 EVSEO-EMSP	
			9-1 CH Back	
Charging Authorization	L: EMSP-CH	OCHP	9-1 CH Back	
			4-1 EMSP Back	
Charging Authorization	K: EVSEO-CH	OCHP	5-3 EVSEO-EMSP	
			9-1 CH Back	
	L: EMSP-CH	OCHP	9-1 CH Back	
			4-1 EMSP Back	

Table 7: TNO Test cases

4.1.3. RSE

The RSE Lab architecture for Interoperability Test in Electro-mobility domain is reported in Figure 17. The dotted lines represent the information exchanges, not compliant to ICT standards, used to support the business process related to the considered use cases. The solid lines represent the information exchanges compliant to specific ICT standard or specification and that consequently will be object of interoperability test.

The actors considered in the architecture include the “Energy Service Provider/User” actor that act as a generic grid side actor that provides or uses “Energy Services” as defined in “Harmonized Electricity Market Role Model” (Figure 3). In EV context this actor could have different roles, for example it could provide “Energy supply services” to the “EV charging system” or “Flexibility Services” to the grid (e.g. to BRP- Balance Responsible Party).

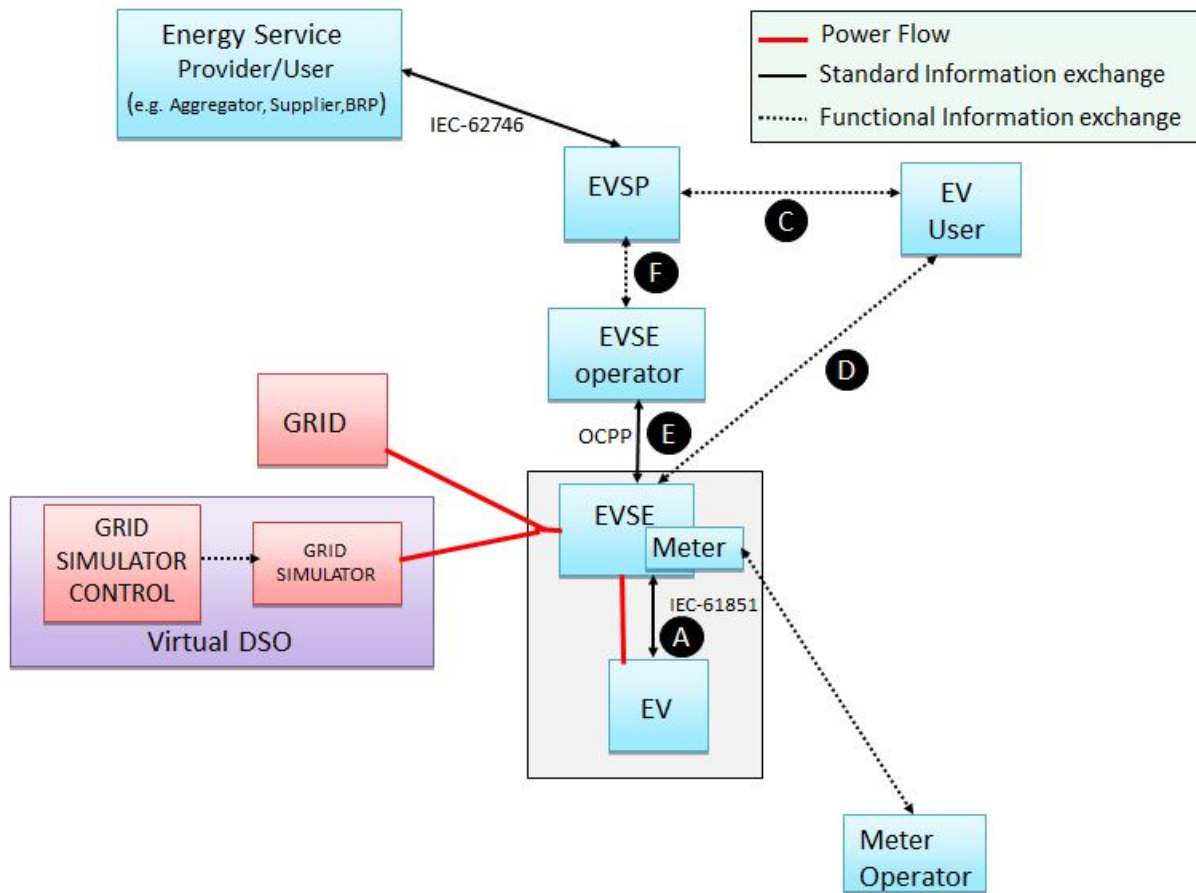


Figure 17- RSE Lab Architecture

More specifically the RSE Lab architecture will consider an electric system flexibility scenario, which will involve the interface between a grid actor (e.g. Energy Supplier/Aggregator¹³/Flexibility Operator) and the “EV ecosystem”.

The “Aggregator” actor supply the “Flexibility Services” to the grid (e.g. BRP) by using the flexibility available by the “EV charging system” (e.g. an EVSE-O or EMSP role). The information exchange related to this interface will be mostly related to commercial information, and can be implemented by means of the IEC 62746¹⁴ standard. It should be noted that the Aggregator could also manage in a similar way the flexibility offered by EVs located in home domain.

In effect the interface between the Actor A and the EMG¹⁵ reported in the functional architecture (Figure 18) proposed by the IEC-62746-2 draft, is functionally equivalent to the interface between the Aggregator and EMSP in RSE Lab architecture.

¹³ An Aggregator is a legal entity that aggregates the load or generation of various demand and/or generation/production units.

¹⁴ Systems interface between customer energy management system and the power management system- Currently in a draft version

¹⁵ The EMG+CEM could manage an EV as a specific kind of Smart Appliance

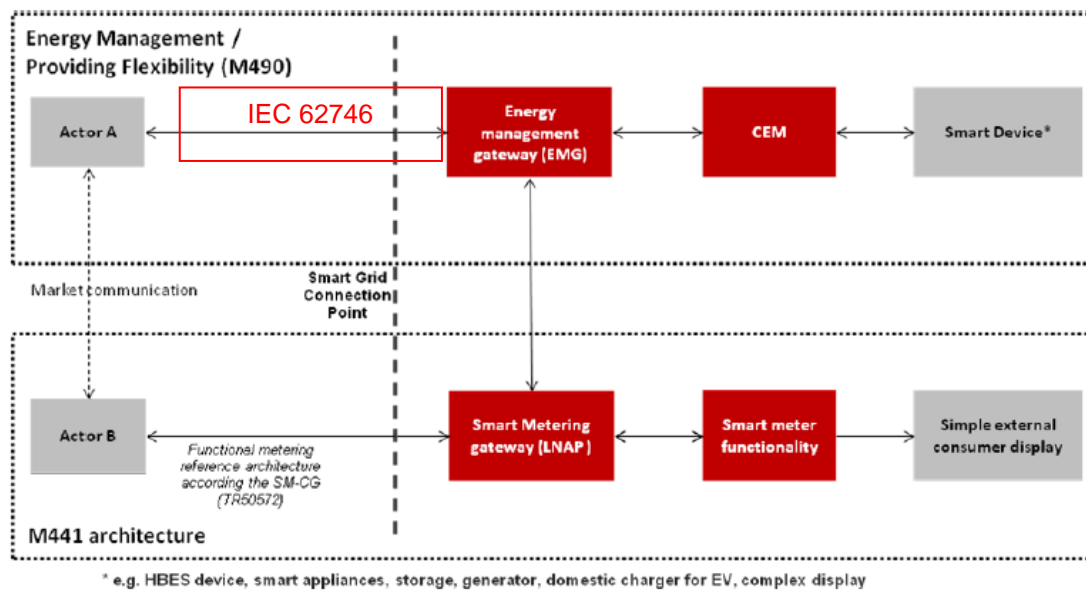


Figure 18- Functional Architecture Model related to grid/customer interface

In this way the Aggregator could use the same IEC-62746 standard solution in order to manage the flexibility offered by EVs both in public (Aggregator - EMSP interface) and in private domain (Aggregator - EMG+CEM interface). The “EV User” actors will be authenticated by the EVSE and will express to EMSP its preferences related to charging time and energy requested. The “Virtual DSO” is implemented through a controllable grid simulator, in case we are testing a real EVSE. An alternative is the connection of the EVSE to a real LV distribution grid, which can be monitored.

Regarding the metering aspect, it should be noted that a Demand Response service requires an adequate advanced metering infrastructure, that should support a reading interval corresponding to the specific time period (e.g. 15, 30 or 60 minutes) requested by the Demand Response functionality. There are two types of use and related information exchange path for the metering data.

A first kind of metering information are collected by the “Meter Operator” and are periodically (i.e. weekly/monthly) sent to the Aggregator in order to define the economic transaction in favor of the Demand Response participants. Another kind of metering information is needed more frequently (i.e. every 15 minutes) for operational objectives and are sent from the meter to the Aggregator by the EVSE-EVSEO-EMSP path.

The test architecture is considering the information exchanges related to the interface between the meter and the “meter Operator” only for a functional support of the Demand Response scenario, without any implementation of a real metering standard interface. On the other hand the information flow from the meter to the Aggregator by the EVSE-EVSEO-EMSP path are concretely realized in the interfaces between the EVSE-EVSEO (OCPP) and EMSP-Aggregator (IEC-62746).

4.1.3.1 Supported test cases

The Lab architecture described above will mainly support the use case specified below.

Name of Use Case : “EV charging system provide secondary frequency regulation to the electrical system using Demand Response functionality”

Scope: “Electric Vehicle charging system provide flexibility services to the Grid by Demand Response incentives proposed by an Aggregator”

Objective: “The use case objective is to optimize EVs users and grid needs”

Narrative of Use Case: “The use case is based on the assumption that the EVs under the control of an EMSP are in charging mode considering the user preferences and the energy needed by the EV charge.



The use case starts when, based on a market request, the Aggregator send a commercial proposal to EMSP in order to provide a secondary frequency reserve service to the grid. The Aggregator proposal is carried out by a Demand Response Event send to the EMSP that will evaluate and eventually manage a load reduction for the EVs under its control for a specific power amount and time slot. The EMSP evaluates the DR request on the basis of its EVs fleet flexibility and confirm to the Aggregator the participation to DR event. The EMSP manages the EVs fleet charging scheduling, considering the time slot and the power reduction requested by the aggregator and the EV user need. In order to monitor the real DR participation during the charging operations, the EV charging infrastructure will collect the metering data related to each EV and send periodically (e.g. 15 min) an aggregate view of them to the Aggregator. When the DR event is finished, the meter operator will send the certified metering data to the aggregator that on this basis will pay the EMSP that in turn will pay the EV users for DR participation.”

The general use case describe above, include the test cases listed below:

TEST CASE	INTERFACE	STANDARD	DUT	COMMENT
USE CASE: charging				
Control of the states	A: EV-EVSE	IEC 61851	EV	
			EVSE	
Control of power (duty cycle)	A: EV-EVSE	IEC 61851	EV control electronics	
			EVSE	
Charging scheduling	A: EV-EVSE	IEC 61851	EV	
			EVSE	
USE CASE: Smart charging				
Send charge details	E: EVSE-EVSE Operator	OCPP	EVSE	
			EVSE0	
Charging loop	A: EV-EVSE	IEC 61851	EV control electronics	
			EVSE	
Handle grid constraints	M: Aggregator - EMSP	OpenADR	EMSP	Check if and how EMSP (and the rest of the system) reacts to commercial offers from an Aggregator

Table 8: RSE Test cases

4.1.4. TECNALIA

4.1.4.1 General description

A – The overall testing platform

As described in Figure 19, TECNALIA's testing environment will cover the following communication interfaces: EV-EVSE, EVSE-EVSE Operator and those supporting a roaming scenario (EVSE Operator-Clearing House and EMSP-Clearing House). TECNALIA already owns infrastructure for the assessment of IEC 61851, however, in the scope of the project TECNALIA will increase its capabilities on this standard, and add new ones dealing with the ISO/IEC 15118 and the OCHP v1.2.

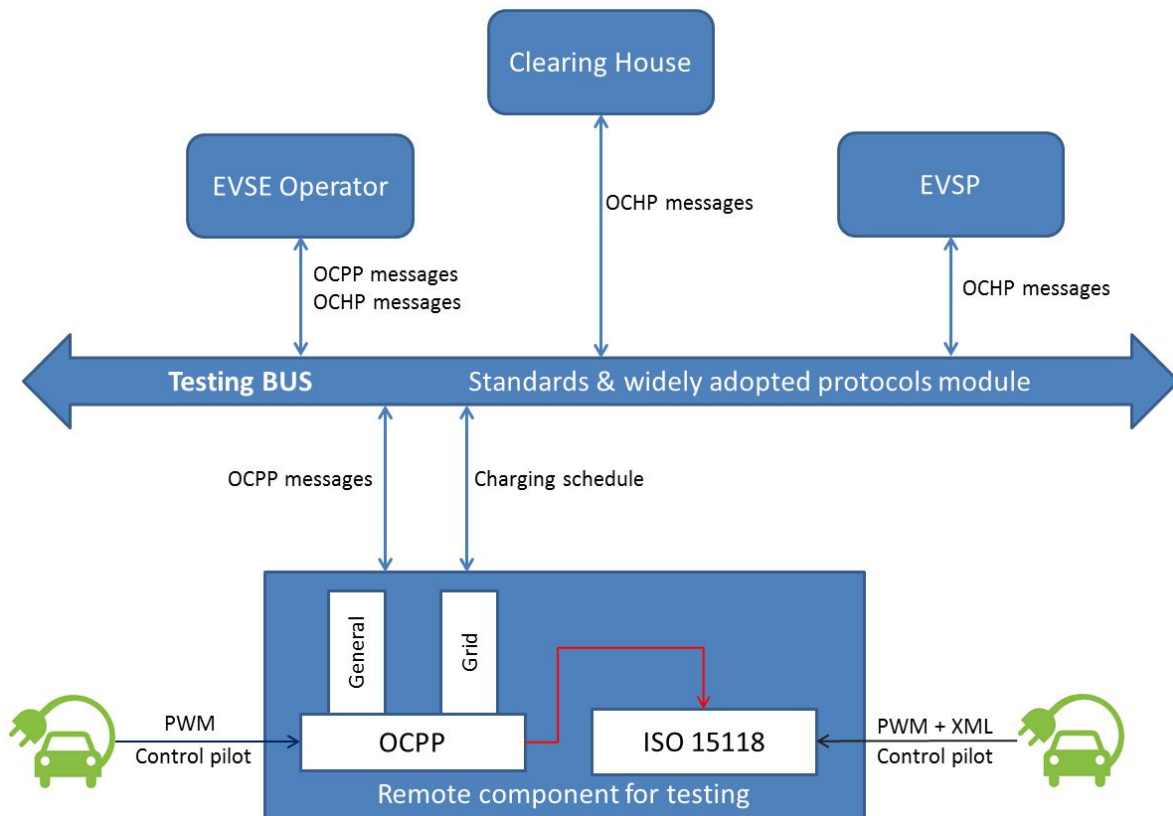


Figure 19: Tecnalia infrastructure for integrating several EV actors

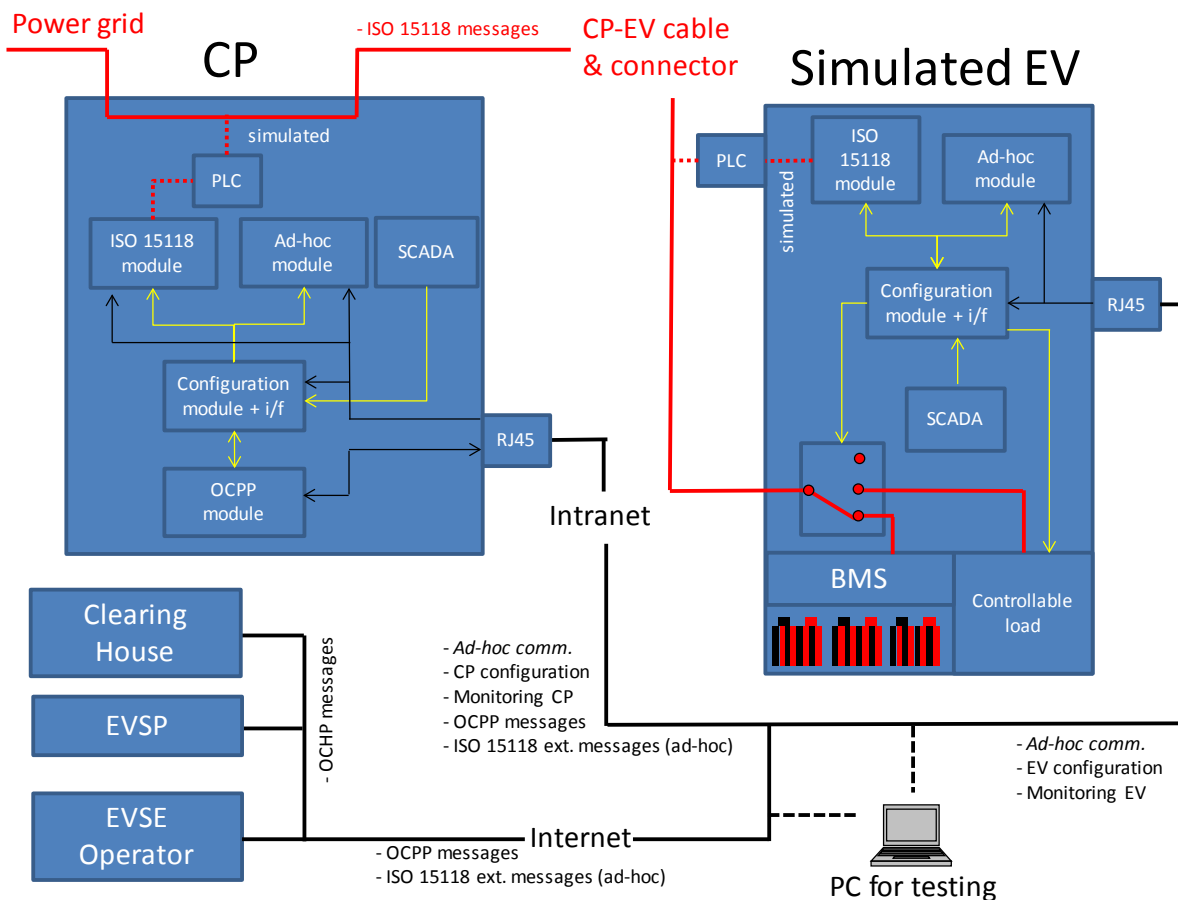


Figure 20: Tecnalia deployment model for EV-EVSE IEC 61851 and IEC 15118 communication protocols

B – The EV-EVSE communication testing infrastructure

TECNALIA's lab capacities for EV charging will comprise two independent physical devices, one module for EVs and another one for testing EVSEs. Both are able to test the IEC 61851 and ISO/IEC 15118 standards.

The 'EV emulator' consists of a battery, BMS, charger, inverter and a small module to manage the charging (or supply energy back to the grid). It also has an electronic circuit that complies with the Control Pilot described in IEC 61851, with its S2 switch, along with a R3 270/1300 Ohm selector for testing EVSEs with or without forced ventilation. In addition, this card provides the necessary sensors for detecting the duty cycle as well as the RC circuit for PWM. The EV emulator uses a low level Ethernet gateway for PLC communication, which is capable of transmitting and receiving any message according to the ISO/IEC 15118 (HomePlug PHY). On top of all, there is a small PC equipped with high-level software able to monitor and manage any charging process. The comprehensive list of the EV emulator capabilities is described below:

- What the EV emulator can do:
 - Charging using only the IEC 61851 standard
 - Charging using both IEC 61851 and IEC 15118 standards
 - It can simulate a normal EV charging session (in automatic mode)
 - Both charging (with and without forced EVSE ventilation) are possible
 - A testing file can be provided in order to drive the charging (for both IEC 61851 and IEC 15118 standards) at any time of the charge.
 - The S2 selector can be opened and closed suddenly
 - The charger can demand more (or less) power than those defined by the EVSE (and sent by means of the Control Pilot)
 - Modify the state machine for sending valid and invalid IEC 15118 messages.
- What the EV emulator can NOT do:



- The SLAC¹⁶ is not implemented. As a result, the NMK¹⁷ must be configured manually for ISO/IEC 15118 testing.

The 'EVSE emulator' is just a real charging point with added infrastructure for EV testing. It consists of the following main parts:

- A module to generate the PWM
- A module to define the duty cycle,
- A dedicated circuit in the Control Pilot for detecting the connected EV according to IEC 61851
- The Proximity Pilot circuit
- A low level Ethernet gateway for PLC communication, which is capable of transmitting and receiving any message according to the ISO/IEC 15118 (HomePlug PHY). This module also implements the SLAC protocol for the EVSE.
- A PC for controlling and testing charging (EVSE-EV charge), as well as all the necessary software for other actors communication, such as the EVSE Operator or the EMSP by means of OCPP.

Its capabilities are the following:

- What the EVSE emulator can do:
 - Charging using only the IEC 61851 standard
 - Charging using both IEC 61851 and IEC 15118 standards
 - It can simulate a normal EV charging session (in automatic mode)
 - Charging with and without forced EVSE ventilation
 - A testing file can be provided in order to control the charging process (according to both IEC 61851 and IEC 15118 standards) at any time.
 - Start/Stop the oscillator suddenly
 - Modify the frequency and the duty cycle of the oscillator
 - Start/stop the power delivery suddenly
 - Modify the state machine for sending valid and invalid 15118 messages
 - Charging according to a defined profile
 - Sending and receiving messages to/from other actors by means of OCPP.

Both devices (EV and EVSE emulators) have TCP/IP capabilities in order to monitor the test remotely on the fly.

C – The EVSE -EVSE Operator communication testing infrastructure

TECNALIA will deploy an EVSE Operator emulator, implementing communications with the EVSE according to OCPP v2.0 protocol.

TECNALIA is developing an EVSE which implements both the IEC 61851 and ISO/IEC 15118. The EVSE (or the EV using the EVSE infrastructure when executing 15118 tests) will communicate with the EVSE Operator by means of OCPP.

We are installing OCPP in the EVSE, although in a first approach we are focusing on the following Web Service operations (those related to authentication and the charging).

Functions that the EVSE will invoke to the EVSE Operator:	
Authorize	Whenever the EVSE Operator receives this function, it will authorize the charging or not (Accepted, Rejected, Scheduled).
TransactionStarted	All these three functions are useful to know all the charging process.
TransactionStopped	
MeterValues	
Functions that the EVSE will be waiting to be invoked from the EVSE Operator:	
RequestStartTransaction	Functions to be used in case the EVSE Operator wants to use remote control of the charging
RequestStopTransaction	
ClearChargingProfile	The EVSE will use the content to perform the charging according

¹⁶ Signal Level Attenuation Characterization, part of IEC 15118

¹⁷ Network Membership Key, part of IEC 15118



SetChargingProfile	to the provided schedule. This will be used in both 61851 and 15118 charging scenarios.
--------------------	---

Table 9: Functions between the EVSE and EVSE Operator

D- Roaming scenario simulation

The design allows the assessment of the different systems involved on a roaming scenario, by carrying out information exchanges according to the OCHP V1.2 protocol.

The clearing house is merely a reactive system, sending messages as response to external events (messages/calls from external EMSPs and EVSE Operators). The main functionalities will provide the requested data to the different actors.

- Functionalities for exchanging Authorization Data
 - Upload/Update own authorisation data (roaming list) to the Clearing House (CHS)
 - Download global roaming authorisation data from CHS
 - Download updates in global roaming authorisation data from CHS
- Functionalities for exchanging Recorded Data for Audit Purpose
 - Upload Charge Data Records
 - Process Charge Data Records
- Functionalities for the exchange of Charge Point information
 - Upload own charge point information to the CHS
 - Download global charge point information from the CHS
- Functionalities for the exchange of charge points live status
 - Update the live status of the own stations
 - Download global live status information
- Functionalities for Charging Process
 - Request to authorize one single token for roaming.

Additionally, functionalities for registering charge point management systems will be also addressed. The Clearing House emulator will provide a web interface allowing the addition, update and deletion of registered EMSPs and EVSE Operators and their related agreements.

On the other side, the EMSP/EVSEO emulators will provide specific test configuration/parameterization files with the different messages to be sent. After receiving the response, they will check the message syntax and output the results to a log file. Emulators will provide a user interface to send messages on demand.

All these communications rely on SOAP v.1.2 over TCP/IP.

4.1.4.2 Supported test cases

TEST CASE	INTERFACE	STANDARD	DUT	COMMENT
USE CASE: CHARGING				
Uncontrolled charging	A: EV-EVSE	IEC 61851	1-1 EV electronics control	only check of EV reaction
			2-1 EVSE	
Control of the states	A: EV-EVSE	IEC 61851	1-1 EV electronics control	only check of EV reaction
			2-1 EVSE	
Control of power (duty cycle)	A: EV-EVSE	IEC 61851	1-1 EV electronics control	only check of EV reaction
			2-1 EVSE	
Charging scheduling	A: EV-EVSE	IEC 61851	2-1 EVSE	
USE CASE: SMART CHARGING				
Initiation of charging process	A: EV-EVSE	IEC 15118	1-1 EV electronics control	



TEST CASE	INTERFACE	STANDARD	DUT	COMMENT
			2-1 EVSE	
Termination of charging process	A: EV-EVSE	IEC 15118	1-1 EV control electronics	
			2-1 EVSE	
Charging scheduling	A: EV-EVSE	IEC 15118	1-1 EV control electronics	
			2-1 EVSE	
Charging loop	A: EV-EVSE	IEC 15118	1-1 EV control electronics	
			2-1 EVSE	
USE CASE: EV USER SERVICES				
EVSE monitoring	E: EVSE- EVSEO	OCPP	2-5 EVSE communication to EVSEO	meaning Monitoring of EVSE operation and status
			5-1 EVSEO CC	
EVSE control	E: EVSE- EVSEO	OCPP	2-5 EVSE communication to EVSEO	
			5-1 EVSEO CC	
EV identification	A: EV-EVSE	IEC 15118	1-1 EV control electronics	
			2-1 EVSE	
			5-3 EVSEO-EMSP	
			9-1 CH Back	
EV authentication	A: EV-EVSE	IEC 15118	1-1 EV control electronics	
			2-1 EVSE	
			5-3 EVSEO-EMSP	
			9-1 CH Back	
EV authorization	A: EV-EVSE	IEC 15118	1-1 EV control electronics	
			2-1 EVSE	
			2-5 EVSE communication to EVSEO	
			5-1 EVSEO to EVSE	
Charging Authorization	E: EVSE- EVSEO	OCPP	2-5 EVSE communication to EVSEO	
			5-1 EVSEO CC	
USE CASE: AUTHORIZATION AND VALIDATION				
Customer ID recognition	D: EV user- EVSE		2-1 EVSE	only RFID, no ISO/IEC 15118
	E: EVSE- EVSEO	OCPP	2-5 EVSE communication to EVSEO	
			5-1 EVSEO CC	
USE CASE: ROAMING SERVICES				
Customer ID recognition	L: CH-EMSP	OCHP	5-3 EVSEO-EMSP	
	K: EVSEO-CH	OCHP	9-1 CH Back	
Exchange EVSE	K: EVSEO-CH	OCHP	5-3 EVSEO-EMSP	



TEST CASE	INTERFACE	STANDARD	DUT	COMMENT
information			9-1 CH Back	
	L: EMSP-CH	OCHP	9-1 CH Back	
			4-1 EMSP Back	
Charging Authorization	K: EVSEO-CH	OCHP	5-3 EVSEO-EMSP	
			9-1 CH Back	
	L: EMSP-CH	OCHP	9-1 CH Back	
			4-1 EMSP Back	
Exchange of points live status	K: EVSEO-CH	OCHP	5-3 EVSEO-EMSP	
			9-1 CH Back	
	L: EMSP-CH	OCHP	9-1 CH Back	
			4-1 EMSP Back	

Table 10: TECNALIA test cases



4.2. COTEVOS Lab Architecture

4.2.1. Goal

The main goal of this section is to define a lab architecture that can be used by all COTEVOS consortium partners. The proposed architecture is however meant to be generic and therefore presumed to be applicable by others with similar demands as well.

The idea behind a common lab architecture is that all partners that have not yet chosen for a specific lab architecture can use the proposed architecture. A common lab architecture will facilitate reuse amongst the COTEVOS partners (although a common architecture is neither a necessary, nor sufficient condition for reuse). Moreover, the interoperability and conformance tests that will be developed within the context of the COTEVOS project are believed to be conducted between different labs more easily if a common lab architecture is used. In general, reuse amongst partners is believed to save valuable time and -as a result- more time can be spent on getting the most out of the COTEVOS project.

Facilitating reuse from others (3rd parties) is expected to be important as well, as it would avoid spending time on implementing functionality that is already available in the market. The COTEVOS lab architecture shall therefore support both kinds of reuse.

Interoperability of the E-mobility ecosystem is tested in the labs, supported by the COTEVOS Lab Architecture. According to the definition by the Working Group Interoperability (WGI), which is working under the Smart Grid Coordination Group (SG-CG), Interoperability is the ability of two or more networks, systems, devices, applications, or components to interwork, to exchange and use information in order to perform required functions [11].

COTEVOS partners agreed that the last objective for interoperability is that any EV user is able to charge easily at any public EVSE. Therefore, when selecting a test case, it should be considered the need for a product to comply with the interoperability requirements of all involved interfaces. When no interoperability conditions are met or defined but that does not hinder the user to perform the desired function easily, the main objective is fulfilled and no interoperability requirement should be asked.

4.2.2. Requirements

For obtaining the requirements that are relevant for the COTEVOS lab architecture, several sources were used. The first sources of information were the proposed lab architectures as described by the COTEVOS partners. Of course, reuse of the architectural elements from these architectures was considered and practised. An even more important aspect was that the requirements that resulted in the proposed (partner) architectures were made explicit.

Next to this also the (partial) solutions/implementations from partners and 3rd parties that can potentially be (re)used within a (COTEVOS lab architecture compliant) test environment shall be considered. For this the available documentation, sometimes enriched by personal explanations, of the considered solutions were used as sources of information.

Taking into account the mentioned sources of information, the high level COTEVOS lab architecture requirements were formulated. This resulted in the requirements that the proposed lab architecture shall:

- *be based on and compatible with the COTEVOS basic reference architecture, described in Chapter 2*

The basic reference architecture provides a common language to describe the lab architecture of the partners and reduces ambiguity regarding actors, services and responsibilities that are used in the use cases and test cases executed by the different partners in the labs;



- *support an environment that helps identifying potential interoperability issues around the (smart) charging of Plug-in Electric Vehicles (PEV)*
For this purpose the lab architecture shall support the execution of complete system use-cases. All systems and actors involved in such system use-cases shall be either physically present, or virtually represented, during the execution of such use-case. As a minimum requirement, the information exchanged by these systems and actors needs to be content-wise correct (i.e. representing the information exchange as supported by the simulated standards/protocols);

- *support the execution of EV-EVSE and EVSE-“back-end” (interface) related conformance tests*
For this purpose, the lab architecture shall support the (highly automated) execution of test scenarios comprising of a real PEV, a real EVSE, or a combination of both. This effectively means that the lab architecture shall support the emulation of a real PEV, a real EVSE and a real “back-end” (as seen from the EVSE). This also means that (the implementation of) all interfaces required by an EV being charged need to be supported and that all interfaces required by a real EVSE need to be supported as well. For executing conformance tests it is required that the execution of all interactions covered by, and the exploration of all boundary conditions defined by, the (set of) standard(s) for given (supported) Interoperability Profiles is feasible and supported by the proposed COTEVOS lab architecture;

- *be scalable in different testing dimensions*
This means that for supporting interoperability tests, the architecture shall be scalable in the level of aggregation (say “vertical scaling”), thereby incorporating more or less communication aspects. As stated before the minimum requirement for executing interoperability tests is that the information exchanged by the implemented systems and actors need to be content-wise correct. In the lab implementations actors can therefore be a real system (fully scaled), an emulated system (fully or partly scaled, but in software defined), or simulated (partly scaled, e.g. only implementing the information aspect of a standard, not the communication aspect). The architecture shall however also support more accurate implementations for the behaviour of the interfaces (such as timing, actual protocol stacks and actual hardware). For conformance tests the architecture shall be scalable in another direction: i.e. covering less/more interoperability profiles (say “horizontal scaling”). See Figure 21.

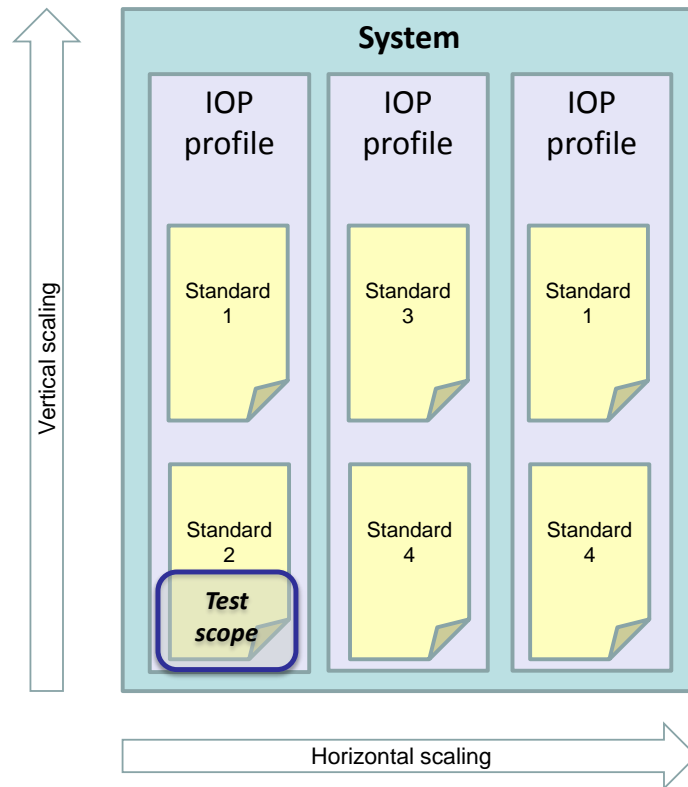


Figure 21: Scaling as requirement for the lab architecture.

In the sections that follow, a lab architecture that complies with these requirements will be described.

4.2.3. Black-box view

The Black-box view considers the functionality of the described system for its end users. The white-box view is out of scope since this is task of the manufacturers of the device or equipment itself. Since COTEVOS focusses on laboratory tests the obvious DUTs are the physical EV and physical EVSE. With this in mind for the COTEVOS Lab Architecture several configurations are supported:

- 1. All actors are emulated or simulated.**
Simulation can take place at different levels of aggregation (“vertical scaling”; taking less/more aspects from the communication interfaces into account). This configuration is typically used for interoperability assessments in which complete system use-cases are executed and where the internal components have (at least) the same information constraints as their real time equivalents.
- 2. All actors are emulated or simulated, except a (software-based) back-end system of an Actor.**
A specific real back-end system is tested (e.g. from a DSO, EMSP, EVSEO, Clearing House, Energy Supplier) against certain test cases regarding (smart) charging. This configuration could for example be used to test certain smart charging algorithms of an EMSP or EVSEO, or see if a Clearing House back-end system can handle numerous simultaneous requests.
- 3. All actors are emulated or simulated, except the (physical) EV.**
A minimum requirement is that the complete EVSE-EV interface is provided (i.e. the EVSE functionality is emulated). This configuration is typically used for executing an EV (smart) charging conformance test for a given interoperability profile.

4. All actors are emulated or simulated, except the (physical) EVSE.

This configuration is typically used for executing an EVSE (smart) charging conformance test for a given interoperability profile.

5. All actors are emulated or simulated, except the (physical) EV and EVSE.

This configuration is typically used for executing a (smart) charging conformance/interoperability test for a given EV-EVSE combination.

The mentioned configurations are visualized in Figure 22. Only two actors are shown: a Test-Operator and an EV-User. The other actors (such as EMSP, DSO, Energy Supplier, Clearing House, etc.) are expected to be simulated and therefore (indirectly) represented by the Test-Operator. However, the proposed lab architecture does not hamper the inclusion of other real-world actors (see configuration 2). Executing conformance tests between other actors than the EV and EVSE seems out of the scope of the COTEVOS project. For executing interoperability tests these other (simulated) actors are however required and therefore covered within COTEVOS Lab Architecture.



Figure 22: Black box view of the different configurations supported by the proposed lab architecture

The COTEVOS Lab Architecture offers the following features:

- a component based representation is provided for the Test-Operator. Each component represents an actor, system, or (back-end) service from the real-world (such as EV, EVSE, EVSE Operator, DSO, Clearing House, etc.).
- the Test-Operator is supported in creating and executing (partially) automated test scenarios. These test scenarios prescribe events from external actors, systems or services.
- the provided component representations can be pre-configured. For the EV and EVSE this includes parameters like maximum (allowed) charging current and the available energy storage capacity (SOC/battery capacity). For the purpose of conformance tests such pre-configuration may even prescribe hardware related settings, like internal resistance, PWM frequency (deviations), noise levels, etc.
- the interfaces of the provided component representations can be connected either physically (for emulators) or logically (for simulators and emulators).
- multiple instances of a simulated component are supported, e.g. tests with multiple EMSPs;
- the EV-User (which role can -of course- also be fulfilled by the Test-Operator) interacts with the DUT(s) as part of the test-scenario to be executed. The EV-user typically provides information about the contract (through a smartcard, a smartphone app, an ID+password) and provides information related with his mobility demand (translated to desired SOC at a given moment).



Notice that different COTEVOS partners may have different implementations of the proposed architecture (this is probably even desirable). Compatibility at the level of test scenarios is however desirable. Re-use of internal components amongst COTEVOS partners is - of course - possible, but will require further commitments of the involved COTEVOS partners regarding the interfaces of the components.

4.2.4. Description of the lab architecture

From the black-box view it can be concluded that each component/service representation shall provide one or more interfaces, thereby allowing the components (once physically or logically “connected”) to exchange information. The exchanged information shall correspond with standard(s) that these components support. To support different levels of aggregation (“vertical scaling”) it is not always necessary that all aspects of a standard are taken into account. The envisioned levels of aggregation¹⁸ are:

1) **Complete**

A complete (interoperability) profile for a given (set of) standard(s) is available, both in hardware as well as in software (i.e. complete communication stack). Example: an EV emulator provides its interface according to SAE J1772 and IEC 61851-1, Annex A. It supports AC charging only and provides support for concurrent IEC 61851-1 and high-level communication through Power Line Communication (PLC), using the Control Pilot (CP) wires and modem, as described in IEC 15118-3. The high level protocol stack is implemented in accordance with IEC 15118-2. The EV simulator from this example does not support authentication (authentication presumed to be done through an RFID card interface on the EVSE). The EV simulator from this example implements the following use-case elements from IEC 15118-1: A2, B1, C1, C2, D3, D4, E1, E2, E3, E5, F0, F1, F2, F3, F4, F5, G2, H1.

2) **Behavioural Complete**

The same as 1), but in this case the actual communication and charger hardware (pilot wire, PWM modulator, modem, charger electronics) is not present. Instead communication is done using different hardware and lower level communication (OSI layers 1 and 2), which could be Ethernet, CAN or even RS232.

3) **Content-wise Complete**

In this case, the information contents of the “supported” standards (and within the standard the supported use-case elements for a given profile) and prescribed sequence of events are considered and mimicked using an inter-process communication messaging solution.

Many of the envisioned architectures from the partners include a combination of real, simulated and emulated components. The COTEVOS Lab architecture is designed such that these component differences are supported, thereby still allowing interactions between real and simulated devices, components and actors. The COTEVOS Lab architecture was designed by analysing all envisioned architectures as documented in Section 4.1. This leads, besides all 8 primary EV actors, the EV OEM secondary actor and the electricity grid as physical infrastructure, also to the identification of the BMS as device and the ‘GUI’ as test infrastructure. The grid and BMS are required to be able to perform all required (physical) test for the DUTs EV and EVSE. The test infrastructure (‘GUI’) is required for the test operator to interface with the test infrastructure and all other components. This contains features like: logging, scenarios editing and execution, visualisation and monitoring reporting. It is expected that (parts) of this test infrastructure can be shared between partners.

The components are interconnected by means of a simulation message bus. This is a well-known pattern in simulation environments. Every component can put messages regarding its state and communication on this bus and receive information and control signals from this bus. Reporting tools can use these messages to see if the interoperability tests are executed correctly and visualisation tools can use these messages to show the Test Operator the progress and status of the tests.

¹⁸ The envisioned levels can be extended or changed without compromising the COTEVOS Lab Architecture

Besides communication through the message bus, direct communication between components is also possible (e.g. the communication between the EVSE and the EVSE0 by means of TCP/IP), albeit no simulation related messages can be (easily) captured from that information exchange.

In the proposed COTEVOS lab architecture there is a clear separation between simulated and real-world components/devices as the simulated components can be directly controlled by a “Scenario Editor/Controller” that allows test-cases to be executed in an (highly) automated way. Separation between simulated and emulated/real-world components allows simulated components to be implemented covering only a few aspects of the supported standards. See Figure 23 for the COTEVOS lab architecture.

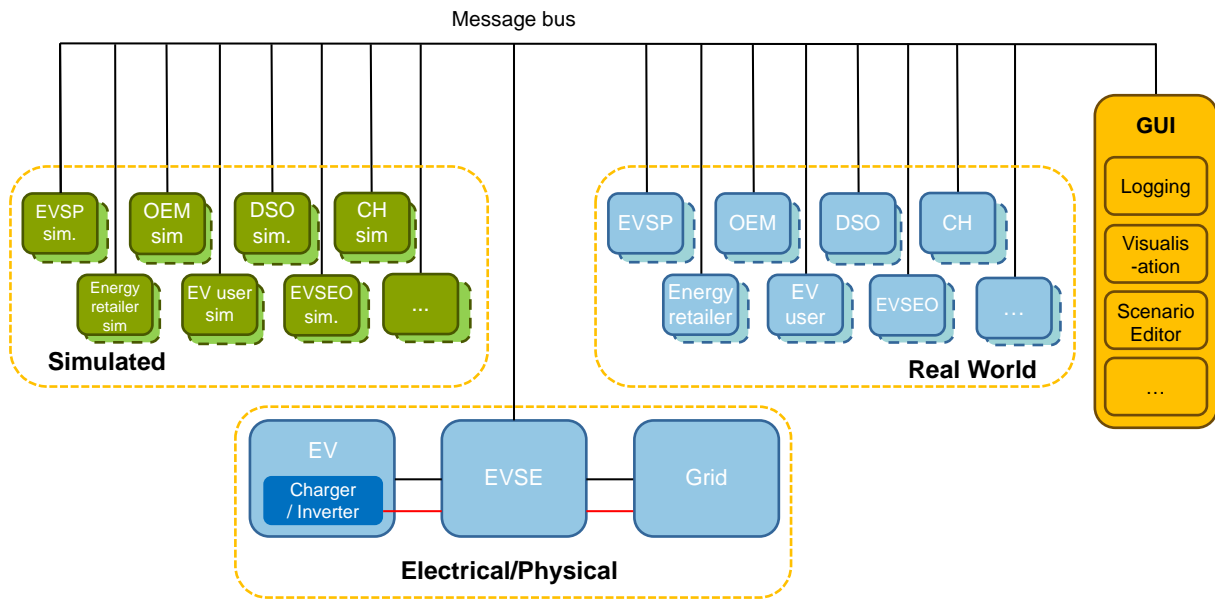


Figure 23: COTEVOS Lab architecture

The COTEVOS lab architecture however also supports the integration of simulated (scenario controlled) components/devices with emulated components/devices residing in a “real-world” context. Controlling the emulated real-world components is presumed to be realized through a proxy mechanism/pattern (see [5] for an explanation). Accessing simulated components/devices is also done through the same proxy mechanism/pattern. Following this approach, the control of simulators and emulators can remain the same from the perspective of the Scenario Editor/Controller and for the Test-Operator. This mechanism facilitates scaling and reuse. A component oriented view regarding applying this pattern in the envisioned COTEVOS Lab architecture is provided in Figure 24.

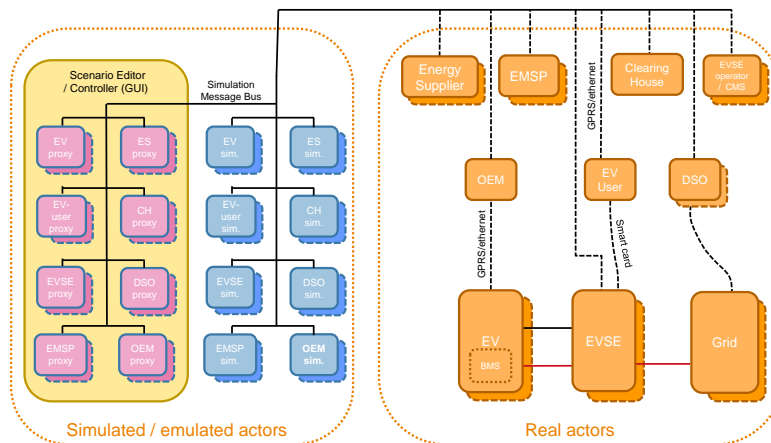


Figure 24: Proxy pattern in the COTEVOS lab architecture.

4.2.4.1 Interoperability focussed tests

In the top left part of the lab architecture will typically be used within an interoperability test focussed simulation environment. In this part (which can be implemented e.g. on a single PC/laptop) simulated components of real-world actors and services will be present. These components can be connected with each other through the (standardized) interfaces that these components provide.

Once connected, the interconnected set of components can be used for executing scenarios/test-scripts. The Scenario Editor/Controller will be used to compose and execute these scenarios/test-scripts. A scenario (in this context) is a time and event controlled set of stimuli. Each stimulus can be either internal or external. An example of an external stimulus is the (presumed) interaction from an actor. An example of an internal stimulus is raising an error condition (for initiating an exception). Next to providing stimuli, the Scenario Editor/Controller can request status info from the component instances through their proxies.

During the execution of a scenario, the Scenario Editor/Controller will apply stimuli to the proxies of the simulated or emulated components. These proxies make sure that these stimuli will end up in the simulated or emulated components, dealing with aspects like marshalling and de-marshalling and thereby using the Simulation Message Bus for exchanging information. The proxies will also make sure that the requested status information is obtained from the simulated or emulated components and provided to the Scenario Editor/Controller (e.g. for the purpose of logging). These aspects are visualized in Figure 25. Notice that the Message Simulation Bus is used for both proxy-stub communication (purple dotted) as well as for inter component (green dotted) communication.

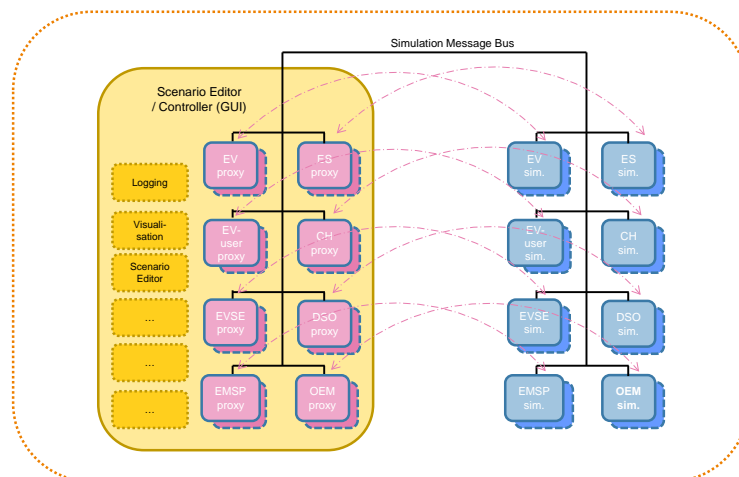


Figure 25: COTEVOS Lab architecture; internal communication during simulator scenario execution

4.2.4.2 Conformance focussed tests

For conformance testing it will be required that all aspects of the tested interfaces are implemented. This typically requires dedicated hardware and corresponding (embedded) software to be used for the emulators. Devices Under Test (DUTs) can be directly connected to these emulators.

For exchanging information with the emulators, the same proxy mechanism is presumed to be used. In that case the proxy connects to an emulator through the Simulation Message Bus. The latter bus is connected with the emulator. In principle, for the Scenario Editor it will make no difference whether a scenario is completely simulated or emulated; only the level of detail contained in the test scripts/scenarios may be different.

The interaction between the Scenario Editor/Controller and the emulators (residing in the “real-world”) is visualized in Figure 26.

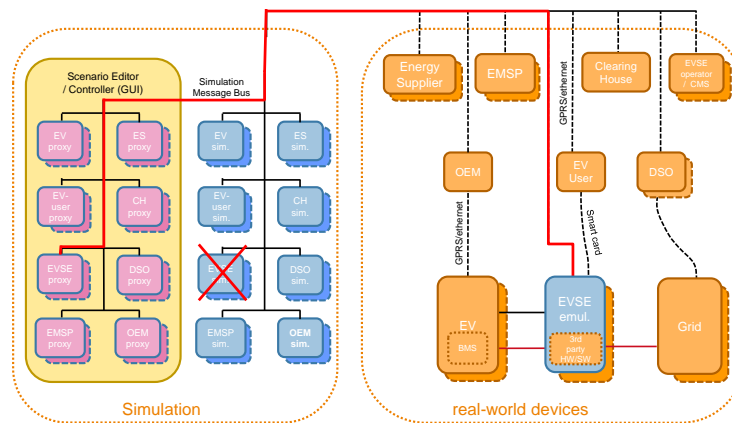
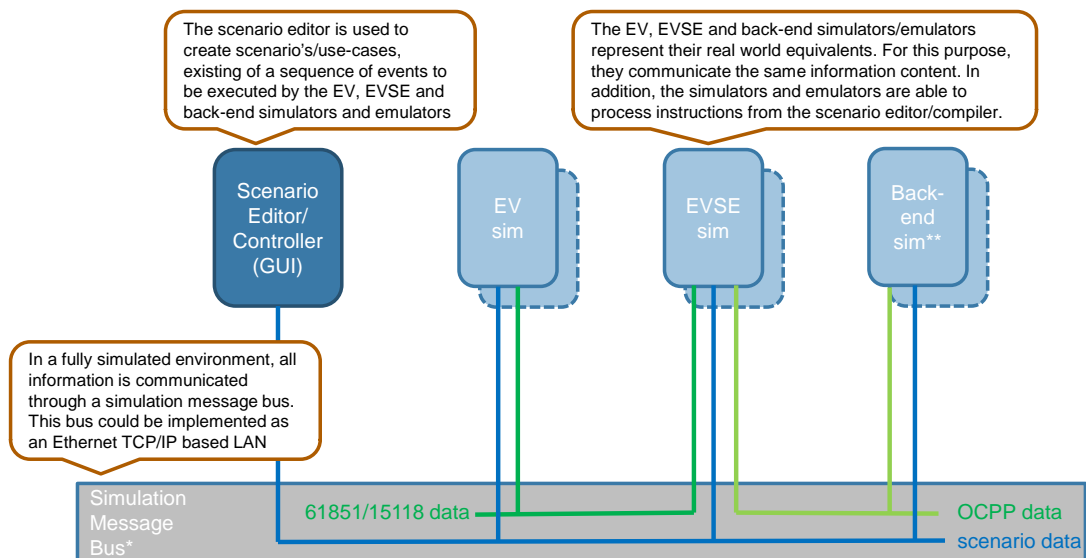


Figure 26: COTEVOS Lab architecture; external communication during emulator scenario execution

4.2.4.3 Electrical/Physical lab infrastructure

This section describes some typical deployment scenarios that show some example lab infrastructure.

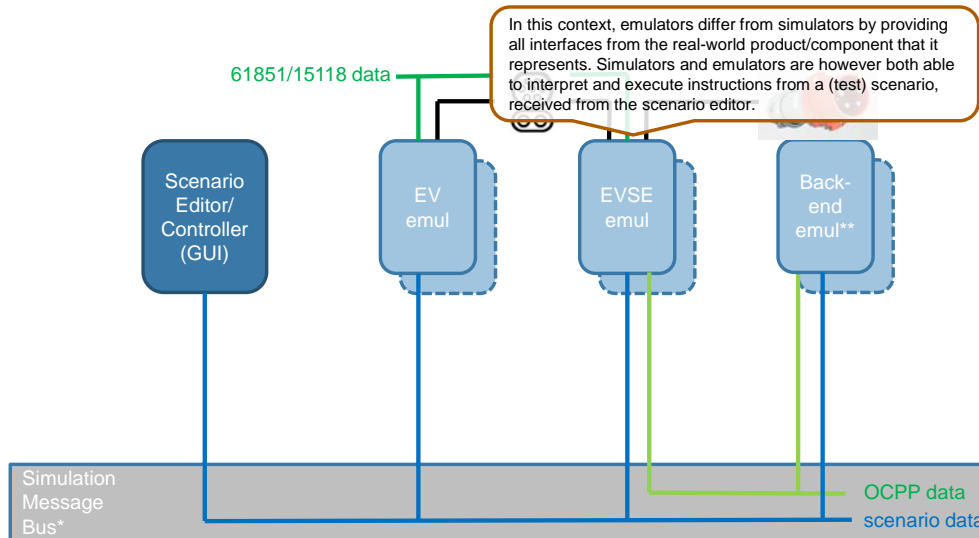


* = e.g. TCP/IP based LAN

** = can be further decomposed into EVSE operator, Clearing House, Energy Provider, DSO, etc. if desired

Figure 27: Electrical/Physical lab infrastructure in a fully simulated environment.

- The scenario editor is used to create scenario's/use-cases, existing of a sequence of events to be executed by the EV, EVSE and back-end simulators.
- The EV, EVSE and back-end simulators represent their real world equivalents. For this purpose, they communicate the same information content. In addition, the simulators are able to process instructions from the scenario editor/compiler.
- In a fully simulated environment, all information is communicated through a simulation message bus. This bus is presumed to be realized as an Ethernet TCP/IP based LAN.

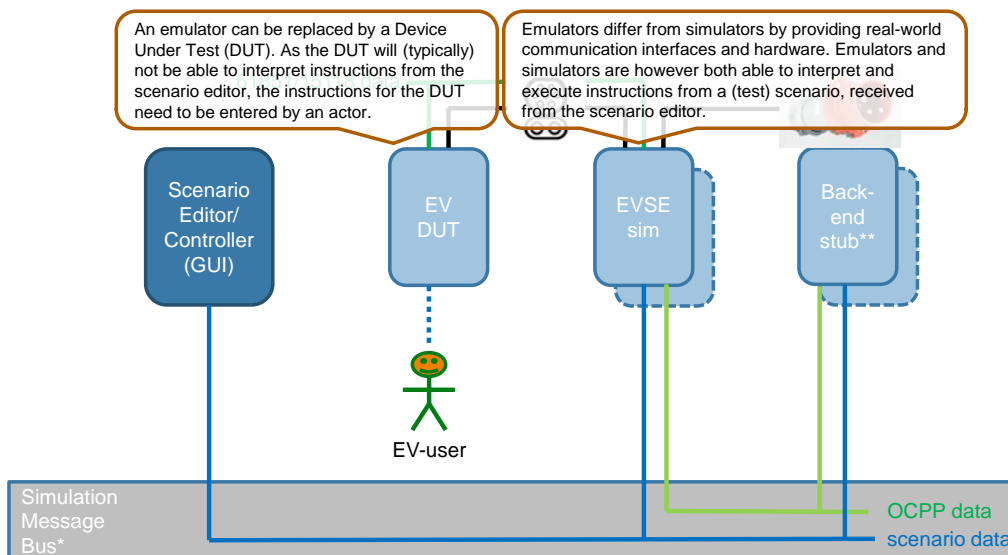


* = e.g. TCP/IP based LAN

** = can be further decomposed into EVSE operator, Clearing House, Energy Provider, DSO, etc. if desired

Figure 28: Electrical/Physical lab infrastructure with a Device Under Test (DUT).

- A Simulator can be replaced by an emulator. There may be more than one emulator of the same type.
- Emulators differ from simulators as they use the real-world communication interfaces and hardware. Simulators and emulators are however both able to interpret and execute instructions from a (test) scenario, received from the scenario editor.
- An emulator can be replaced by a Device Under Test (DUT). There may be more than one Device Under Test (DUT).



* = e.g. TCP/IP based LAN

** = can be further decomposed into EVSE operator, Clearing House, Energy Provider, DSO, etc. if desired

Figure 29: Electrical/Physical lab infrastructure with a Device Under Test (DUT).



4.3. Commonalities and gaps regarding the laboratories

4.3.1. Real, emulated and simulated actors between the laboratories

The table below describes which actors are present as a real device (**Real**), an emulated device (**Emulated**, replaces the real but is fully functional) or can be simulated (**Simulated**, simulates part of the functionality, e.g. uses the correct fields of information, but not the required protocol, if any).

	TECNALIA			AIT			RSE			TNO		
	Simulated	Emulated	Real	Simulated	Emulated	Real	Simulated	Emulated	Real	Simulated	Emulated	Real
Energy Supplier				X			X			X		
Distribution System Operator				X						X		
Grid				X	X	X	X		X	X		
EV			X	X	X	X	X		X	X		
EV user				X		X	X			X		X
EVSE			X	X*	X*	X*	X		X	X		X
EVSE Operator	X			X			X			X		
EMSP	X			X			X			X		
Clearing House	X	X								X		

Table 11: Overview of which actors are present in each lab architecture (* denotes only AC EVSE)



4.3.2. Supported test cases in COTEVOS laboratories

TEST CASE	AIT	TNO	RSE	TECNALIA
USE CASE: CHARGING				
Uncontrolled charging	X	X		X
Control of the states	X	X	X	X
Control of power (duty cycle)	X	X	X	X
Charging scheduling	X	X	X	X
USE CASE: SMART CHARGING				
Initiation of charging process		X		X
Termination of charging process		X		X
Charging scheduling		X		X
Charging loop		X	X	X
Send charge details		X	X	
Handle grid constraints		X	X	
USE CASE: EV USER SERVICES				
EVSE monitoring	X			X
EVSE control	X			X
EVSE reservation				X
EV identification				X
EV authentication				X
EV authorization				X
Charging Authorization		X		X
USE CASE: AUTHORIZATION AND VALIDATION				
Customer ID recognition	X	X		X
USE CASE: ROAMING SERVICES				
Customer ID recognition		X		X
Exchange EVSE information				X
Charging Authorization		X		X
Billing				X

Table 12: Overview of the targeted supported test cases in COTEVOS laboratories



4.3.3. Analysis of commonalities and gaps

4.3.3.1 Commonalities

A first impression shows that COTEVOS is able to test real EV's, EVSE's and EV users in the different laboratories, and as such enabling round robin tests for EV's and EVSE's. All other actors are either simulated or emulated to create a functional interoperability test. The simulated or emulated actors are for all actors available in at least three laboratories.

4.3.3.2 Gaps

One of the gaps identified with respect to the laboratories is that the actors at the upper part of the reference architecture can only be simulated, i.e. interfaces towards the Energy supplier (interface N and M, where OpenADR might be a candidate) and the DSO (interface H and I, where OSCP might be a candidate). Another gap is the interface between the EVSE Operator and the EMSP (interface J). Consequently, testing the interoperability of smart charging functionality in that area might take a while, as there are no standards yet to test or to be compliant with.

Actually, this is not a gap in the laboratories itself, but a gap in the specification of the overall e-mobility and especially Smart Grid system. The area around EVSE, EV, and thus also EV user and physical grid connection is relatively well documented and standardized.

The e-mobility system is not uniformly specified but several implementations and combinations of EVSE Operator, EMSP and Clearing House exist and can be taken as references.

The Smart Grid system is much less specified. Key actors in this Smart Grid system will be the Energy Supplier and DSO. Real implementations do not exist yet, but several use cases are available. This combined with the Smart Grid knowledge of the COTEVOS partners and their communities will be used to define smart charging use and test cases, covering expected future functionality.

So the gaps are closed as much as possible taking the current status of standards and standardisation activities into account. It is only possible to test according to a specification or standard. If neither are there then only (expected) use cases can be tested.

There is no gap in the COTEVOS lab architecture itself. It covers all current and foreseen actors, systems and infrastructures.



Green eMotion FP7 project, eMI3, and the CEN/CENELEC/ETSI group on Smart Charging and the Smart Grid Coordination Group's activities mandated in M/490 by the European Commission.

In analysing the interfaces between the actors the interface J (interface between the EVSE Operator and EMSP) is identified as a gap, as no known standards are available there to test interoperability (i.e. current real-world implementations – if available – use a proprietary protocol). This also holds for interfaces N and M (interfaces towards the Energy Supplier) which could be covered by OpenADR in a future iteration and interfaces H and I (towards the DSO) where the Open Smart Charging Protocol could be a candidate.

5.2. Service architecture

The COTEVOS Service architecture describes the e-mobility system architecture from a (business) service point-of-view. This architecture describes all the services and functions present in the basic reference architecture and allows us to define the responsibilities of each actor in the e-mobility system, and creates a stable interface architecture.

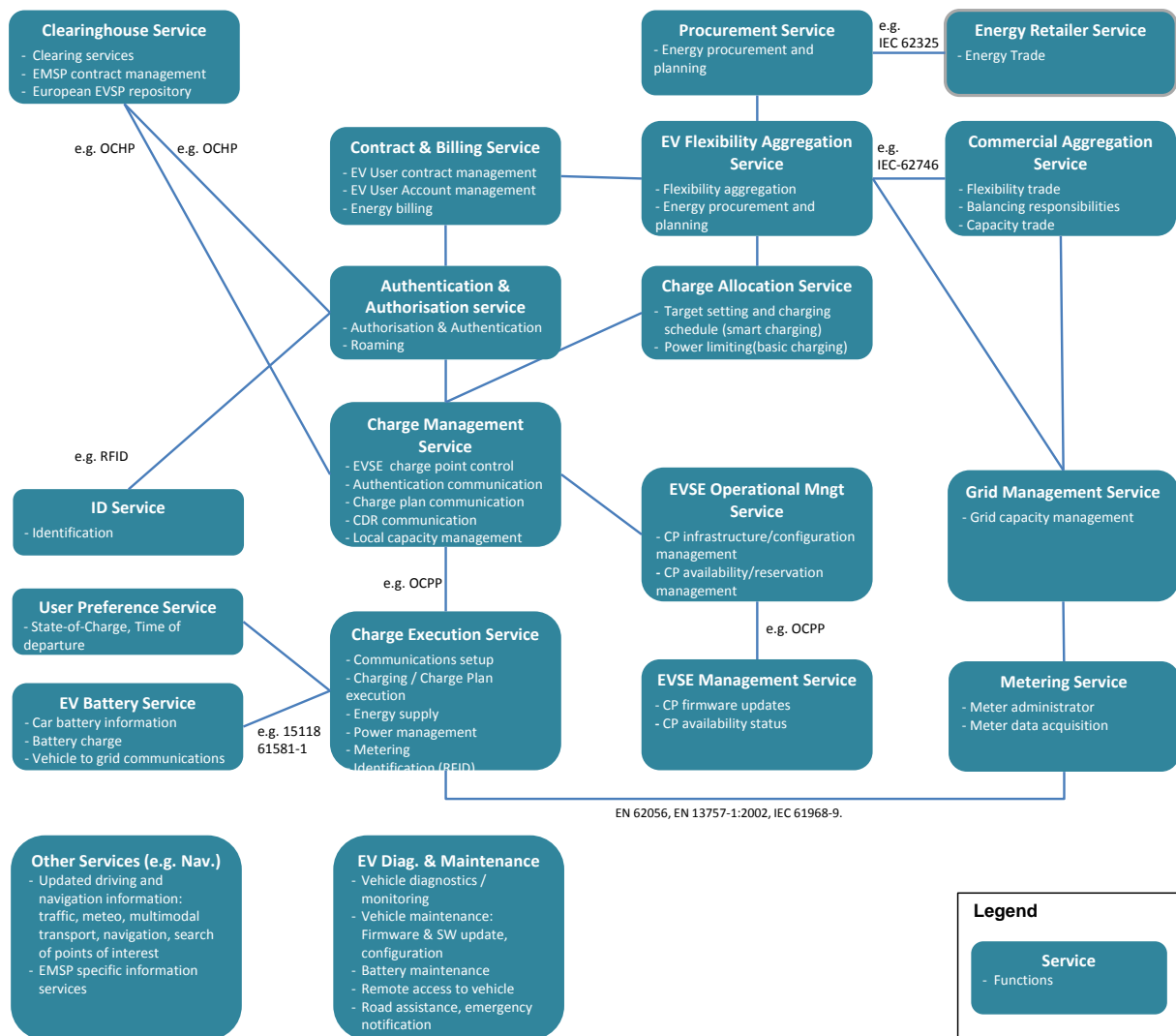


Figure 31: COTEVOS Service architecture of the EV ecosystem

The service architecture described in this document has been accepted and agreed upon by all partners in the COTEVOS project. The concept has also been endorsed by eMI3 (the e-mobility ICT Interoperability Innovation group).

5.3. Lab architecture

The COTEVOS Lab architecture describes the common COTEVOS architecture that is used in the labs of the partners.

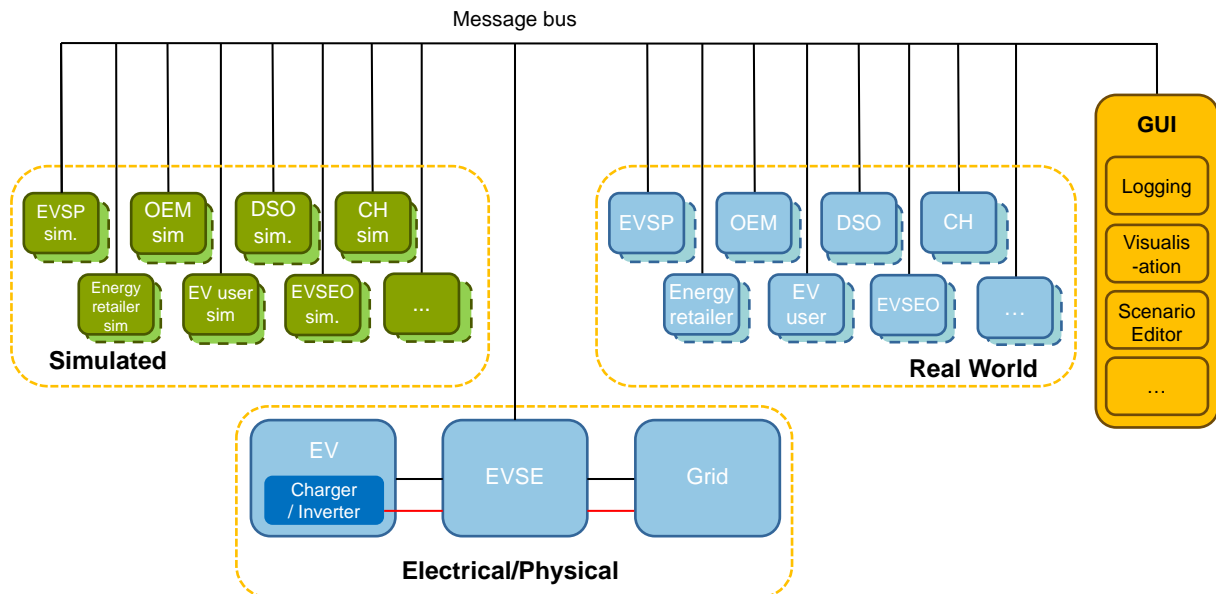


Figure 32: COTEVOS Lab architecture

This Lab Architecture is based on the current practices in the laboratories while taking into account reuse (e.g. exchanging components among the partners), compatibility with the basic reference architecture, and scalability in different testing dimensions. It supports an environment that helps identifying potential interoperability issues around the (smart) charging and V2G use cases and supports the execution of conformance tests.

It was in the process of defining the lab architecture that it was noticed that it was necessary for the task partners to agree upon and describe the basic reference architecture together with the service/function architecture to create a common understanding of the actors and the interfaces involved while testing.

Furthermore, the 9 actors from the basic reference architecture need to be extended with the (electrical) grid, and the charger/inverter (or Battery Management System) of the EV as first class physical entities in the Lab Architecture. Additionally, a GUI is needed to provide the ability to setup test scenarios, visualise the tests and report on the tests.

The different test cases (to be) implemented by the labs described in this deliverable show a neat coverage of the available test cases. It shows that each lab has a different focus (and expertise) , together covering the complete e-mobility ecosystem.

The missing standards ('gaps') identified in the basic reference architecture can be dealt with in the laboratories by taking several implementations and combinations of EVSE Operator, EMSP and Clearing House into account that currently exists as a reference. Since the Smart Grid system is much less specified, testing the interfaces of the key actors in this Smart Grid system (e.g. the Energy Supplier and DSO) is difficult. Real implementations do not exist yet, but several use cases are available. Combining this with the Smart Grid knowledge of the COTEVOS partners and their



communities will allow COTEVOS to define smart charging use and test cases, covering expected future functionality.

So some of the identified gaps are closed as much as possible by taking the current status of standards and standardisation activities into account. Since one can only test according to a specification or standard, only (expected) use cases can be tested if both are not available.

There is no gap in the COTEVOS Lab Architecture itself. It covers all current and foreseen actors, systems and infrastructures. Furthermore, it shows that COTEVOS is able to test real EV's, EVSE's and EV users in the different laboratories, and as such perform round robin tests for EV's and EVSE's which will be completed in WP 4.

All other actors are either simulated or emulated to create a functional interoperability test. All simulated or emulated actors are available and implemented in at least two laboratories.



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