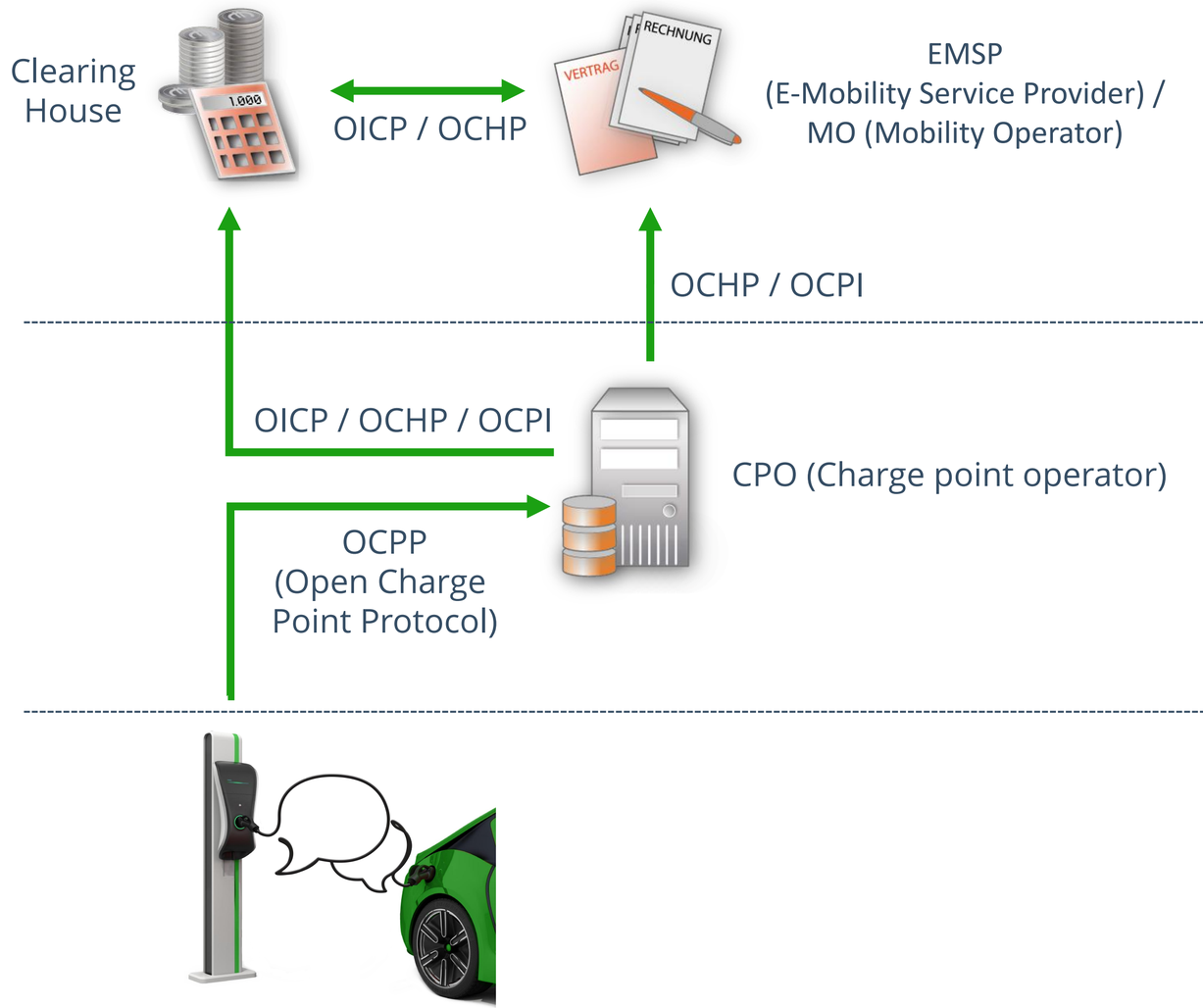
Communication Protocols for Electric Vehicle Charging – Meet ISO 15118-20

Newcastle University Webinar | Nov. 26, 2019

E-Mobility Communication Stack



OICP (Hubject) / OCHP (e-clearing.net) / …
- Roaming protocols between CPOs and EMSPs

IEC 63119 (kickoff in early 2017)
- „Information exchange for electric vehicle charging roaming service“

Open Charge Point Protocol (OCPP)
- De facto standard for communcation between CPO and charging station

IEC 63110 (kickoff in early 2017)
- „Protocol for management of electric vehicles charging and discharging infrastructure“

ISO 15118
- Standard for digital communication between EV and charging station

IEC 61851
- Safety-related analog PWM-signalling

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ISO 15118 Use Cases

One Communication Solution for All Charging Needs

Automated authentication & authorization

- Two authentication & authorization mechanisms:
  External Identification Means (EIM) and more **user-friendly and secure Plug & Charge** (PnC)
- Plug & Charge enables security mechanism on transport layer (**TLS**)
  and application layer (digital **XML-based signatures** and **digital certificates**)

Automated billing

- Plug & Charge enables secure and automated billing via **e-mobility contract**

Optimized load management for AC (and DC) charging

- **Cost-, renewable-**, and **battery-optimized charging** with support for load levelling
- **Fleet-charging management** and **grid services** (e.g. provisioniong of balancing power) possible
- **(Re-)Negotiation** of **charging schedules** to quickly react upon unforeseen changes in grid situation

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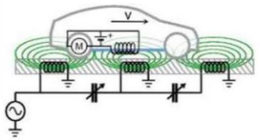
ISO 15118 Use Cases

One Communication Solution for All Charging Needs

Additional value-added services (VAS)

- Access to **Internet-based services** via separate HTTP(S) and FTP communication channels (vendor-specific VAS are possible)

ISO 15118-20 (Q4 / 2020)



Wireless power transfer (WPT)

- WPT and Plug & Charge in combination guarantee **most convenient customer experience**
- **One wireless communication channel** for fine-positioning, pairing, and charge control

Bidirectional power transfer (BPT) for real **smart grid support**

Automated connection device (ACD)

- Support for **high power DC charging of electric busses** for public transport
- **Control of pantograph** for connection / disconnection

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Charging Standards Compared

	DC	AC	Security	Plug & Charge	Smart Charging	Wireless Power Transfer	Bidirectional power transfer	ACD (Pantograph for busses)
DIN SPEC 70121 (2012 / 2014)	✓							
CHAdeMO[1]	✓						✓	
ISO 15118-2 (2014)	✓	✓	✓	✓	✓			
ISO 15118-20 (2020)	✓	✓	✓	✓	✓	✓	✓	✓

➡ ISO 15118 serves all use cases to enable seamless market introduction of Evs (cars, bikes, trucks, buses, ships, airplanes)

1: Bandwidth limited due to CAN-based communication. HomePlug Green PHY (used in DIN SPEC 70212 and ISO 15118) allows for bandwidth of 10 Mbps and data security due to TCP/IP-based communication.

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The ISO 15118 Document Family

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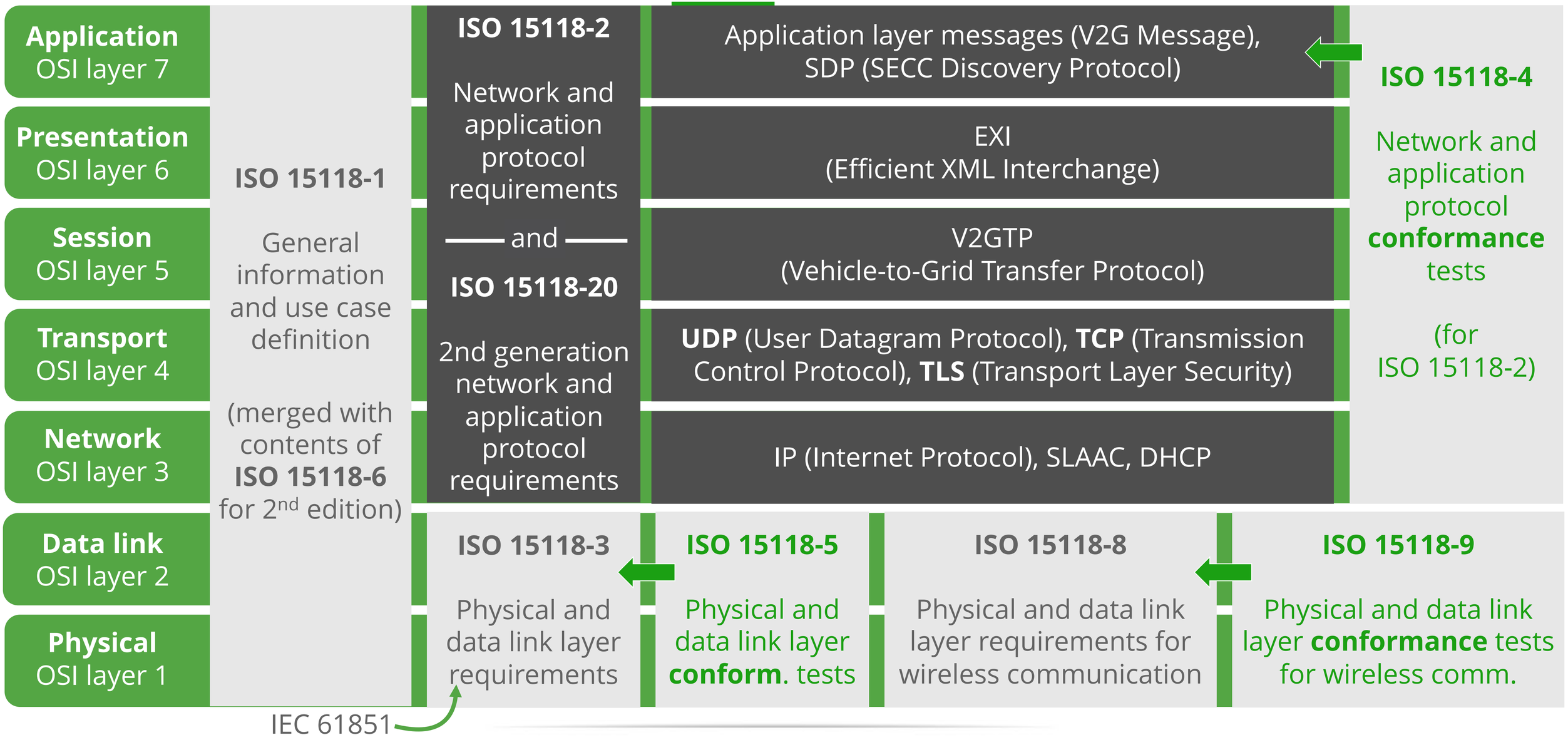
ISO 15118 Parts and OSI Layers



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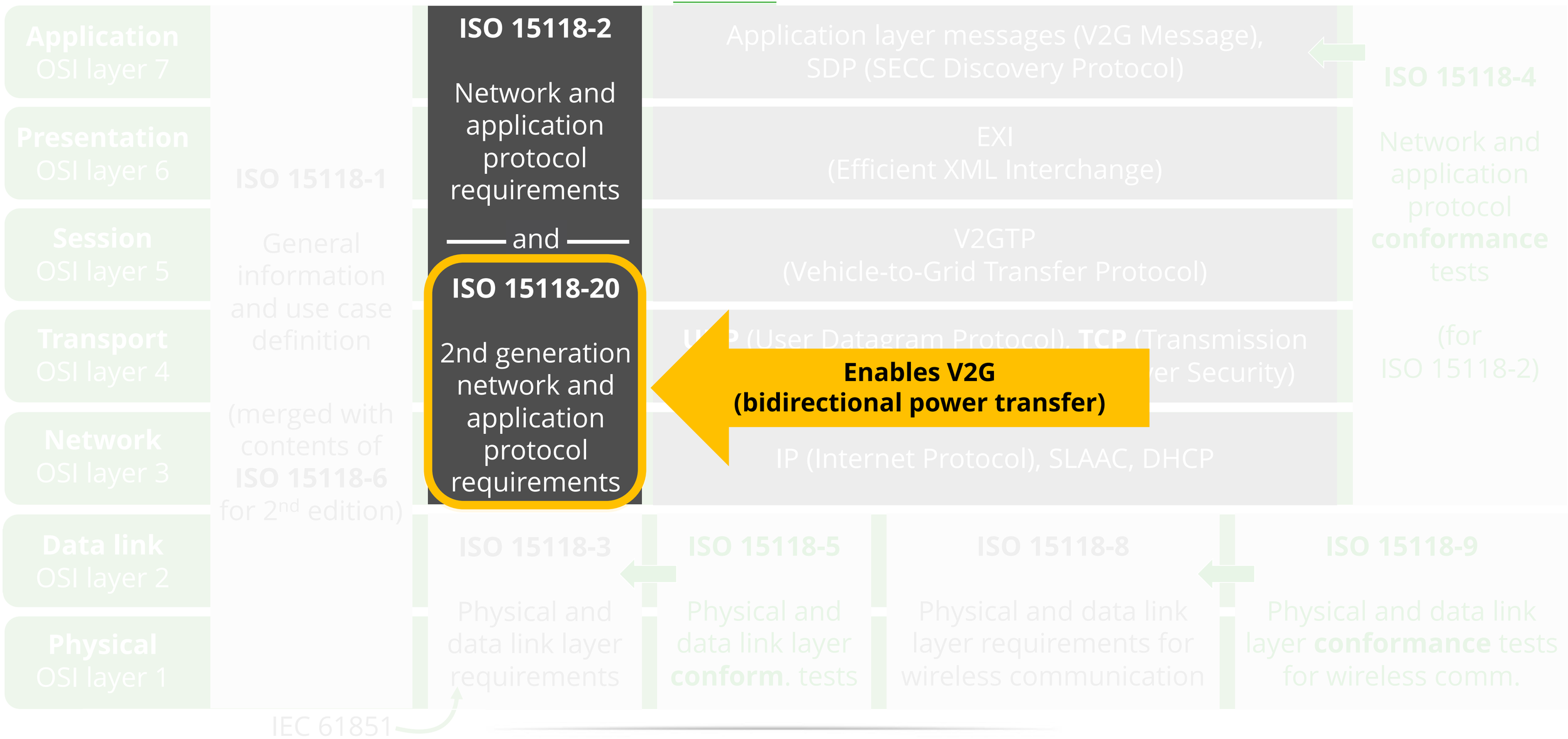
ISO 15118 Parts and OSI Layers



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Grid Codes – Safeguarding V2G

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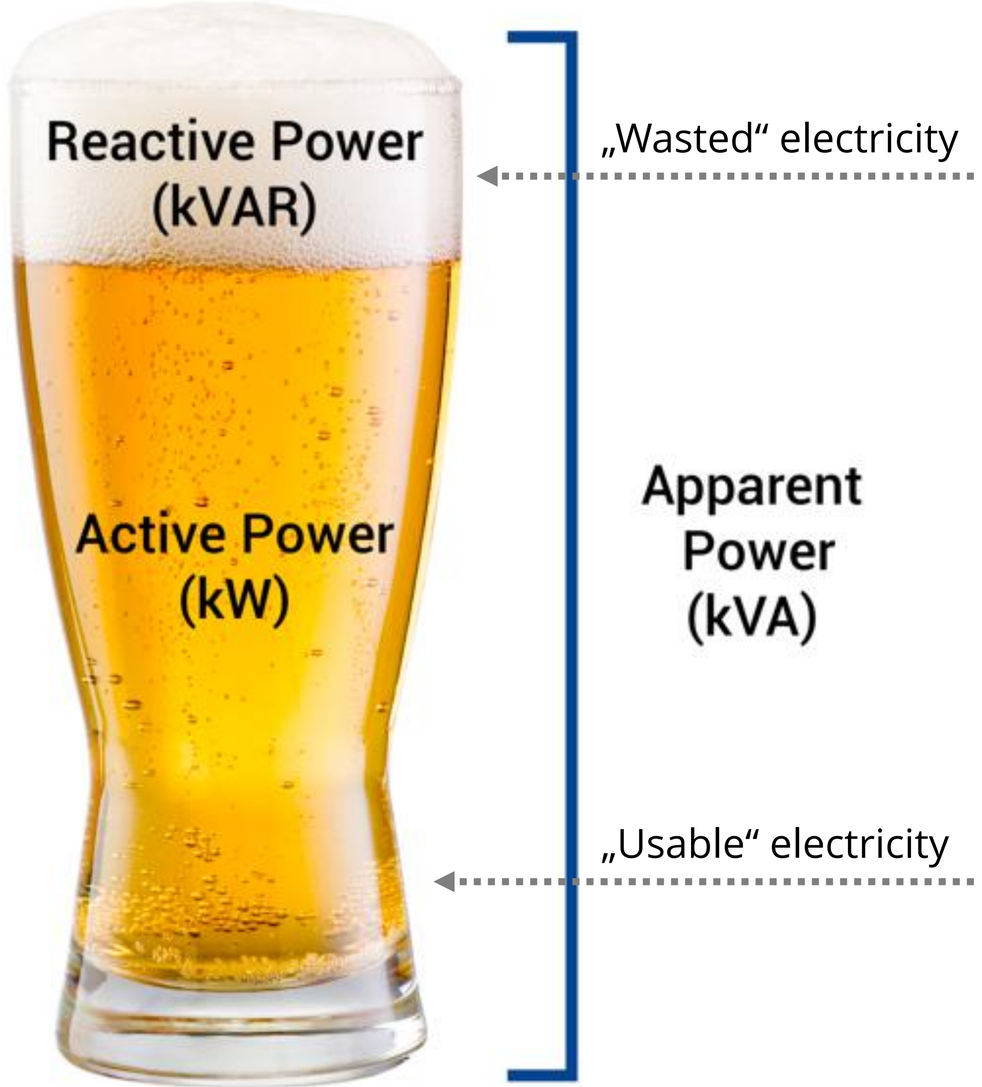
Vehicle-to-Grid – Let‘s Talk About Grid Codes

Grid codes

Technical regulations that any generating device connected to the grid needs to comply with in order to **guarantee a stable operation of the electrical grid**.

Includes
- voltage regulation
- **power factor** limits (usually 0.9 – 0.95)
- reactive power supply
- response to short-circuits / frequency changes on the grid

$$\textbf{Power Factor} = \frac{\textbf{Active power (Wirkleistung, kW)}}{\textbf{Apparent power (Scheinleistung, kVA)}}$$



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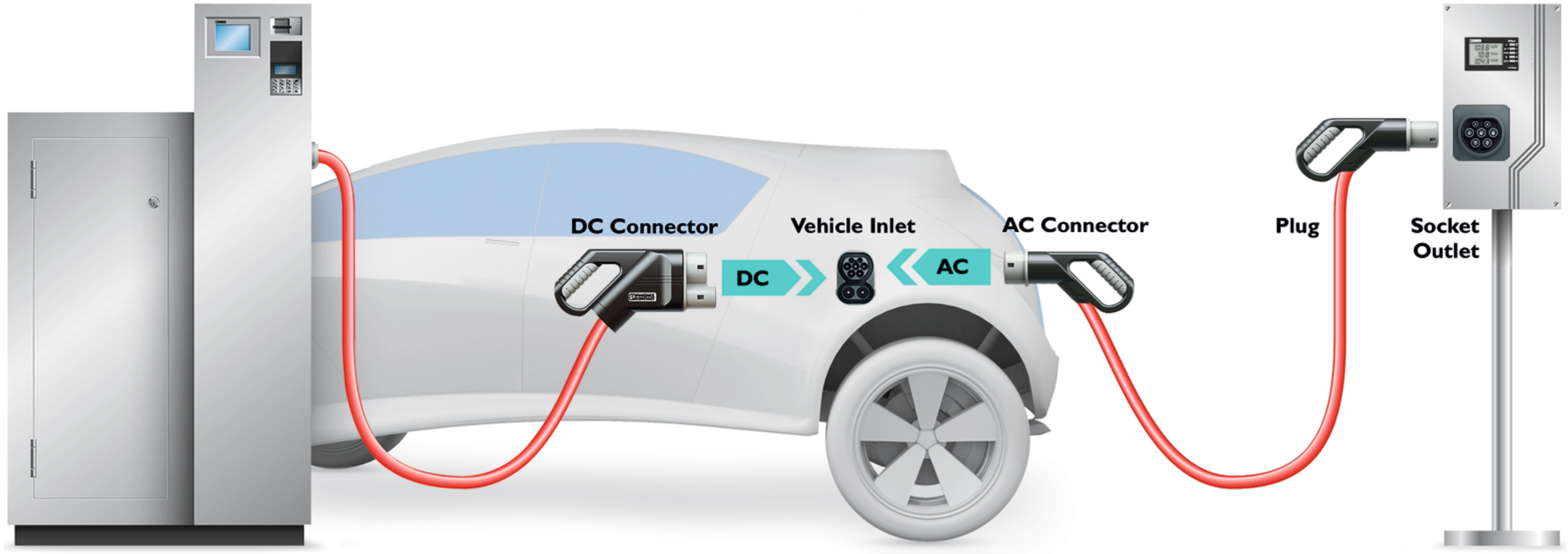
Handling Grid Codes In AC and DC Charging



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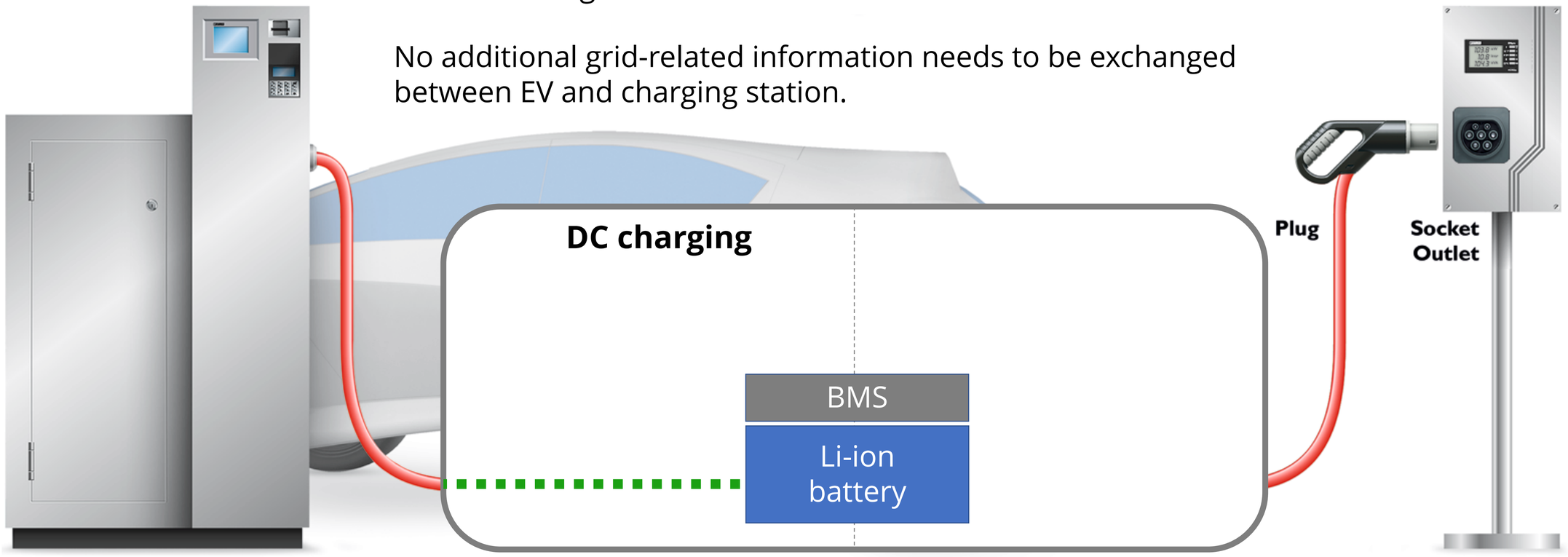
DC Charging Simplifies Grid Code Handling

DC charging

Power converter is located „off-board“ in the charging station. **Location-dependent grid codes** can be **programmed into the controller of the charging station** which manages power flow to and from the grid.

No additional grid-related information needs to be exchanged between EV and charging station.



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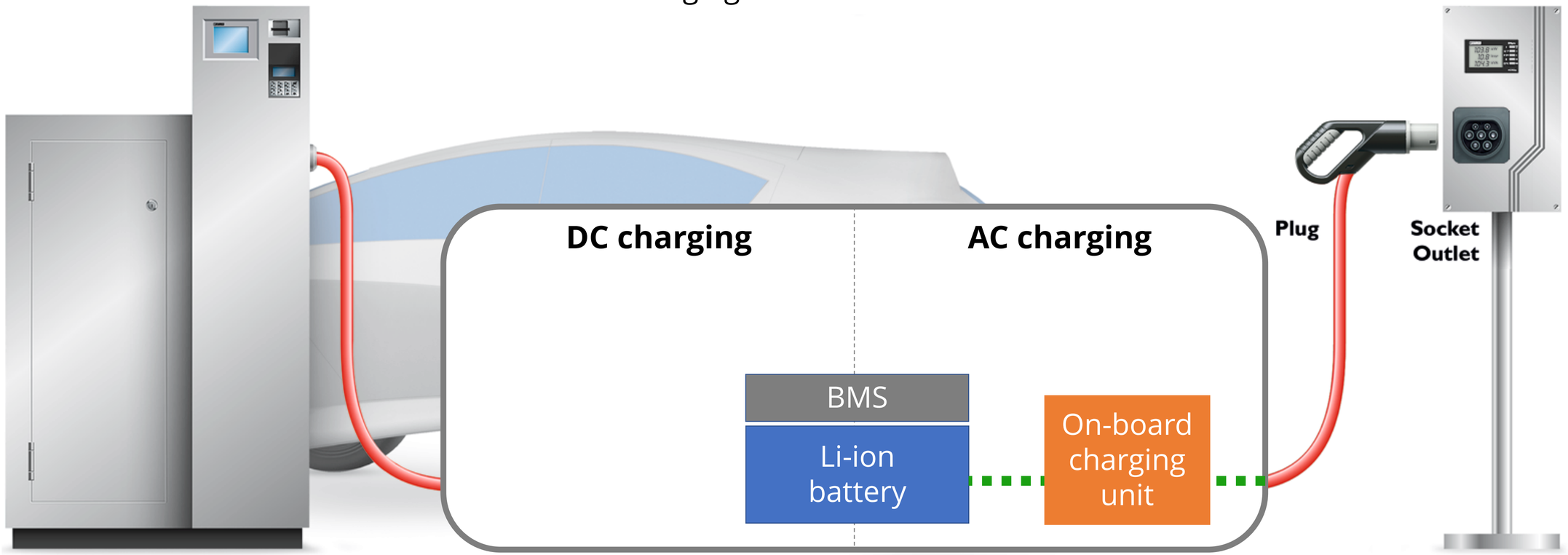
AC Charging Requires Additional Communication

AC charging

Power converter that manages power flow is located „on-board“ (**inside EV**). Technical requirements needed to **clearly specify which information needs to be exchanged** between EV and charging station.



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AC Charging
Message Sequence

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ISO 15118 – A Client-Server Protocol

- Electric Vehicle Communication Controller (**EVCC**) acts as client
  Supply Equipment Communication Controller (**SECC**) acts a server
- SECC can trigger certain request messages by setting a flag in response message
  (e.g. for **renegotiation of charging schedule**)

Server

Responds within
2 sec to 5 sec
to incoming request
(depending on message)

Client

Sends request every
60 sec at the latest

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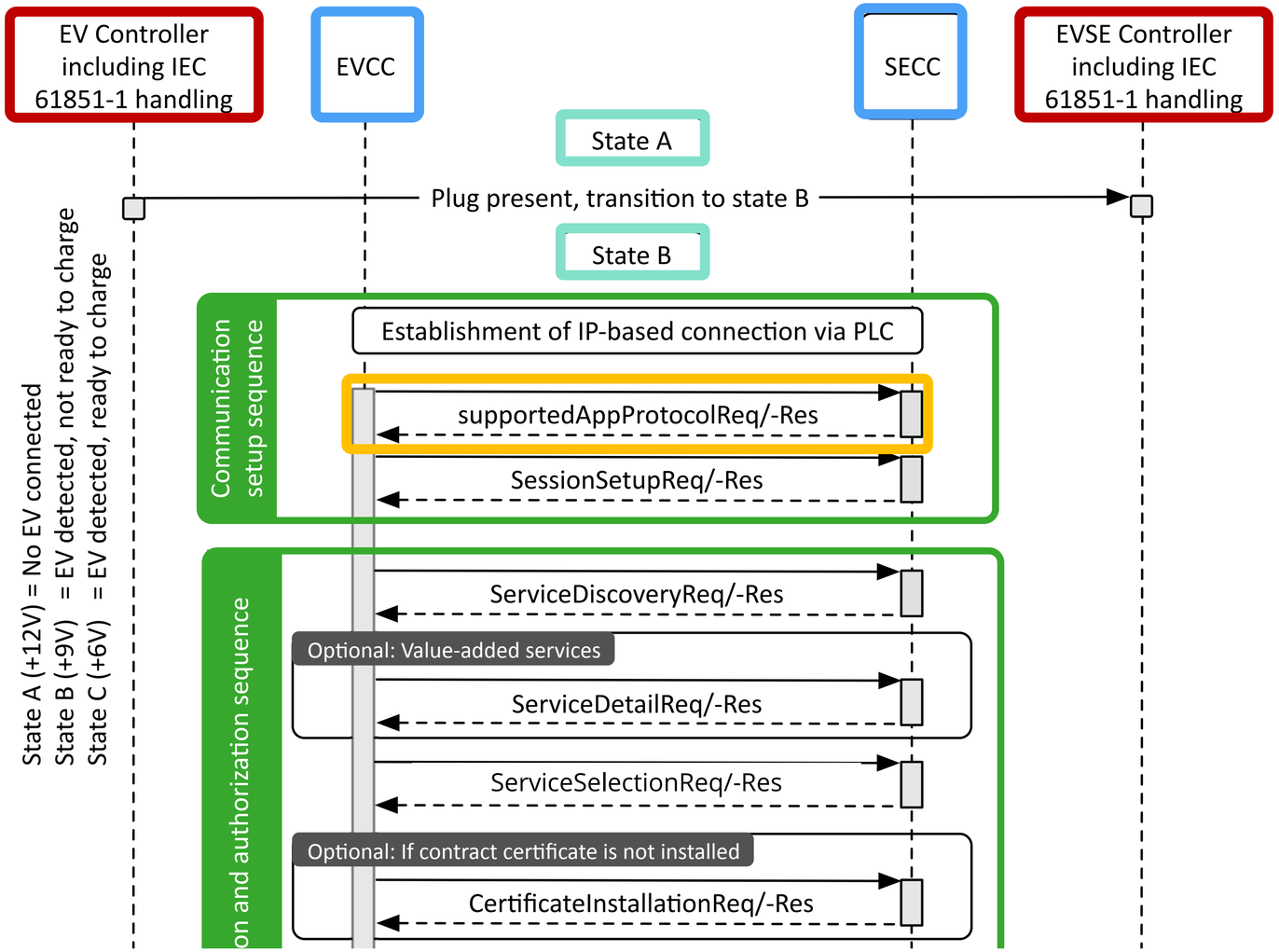
AC Message Sequence

States

Hardware and analog signal handling

Communication controllers

Request-response message pairs



Source: ISO 15118 Manual

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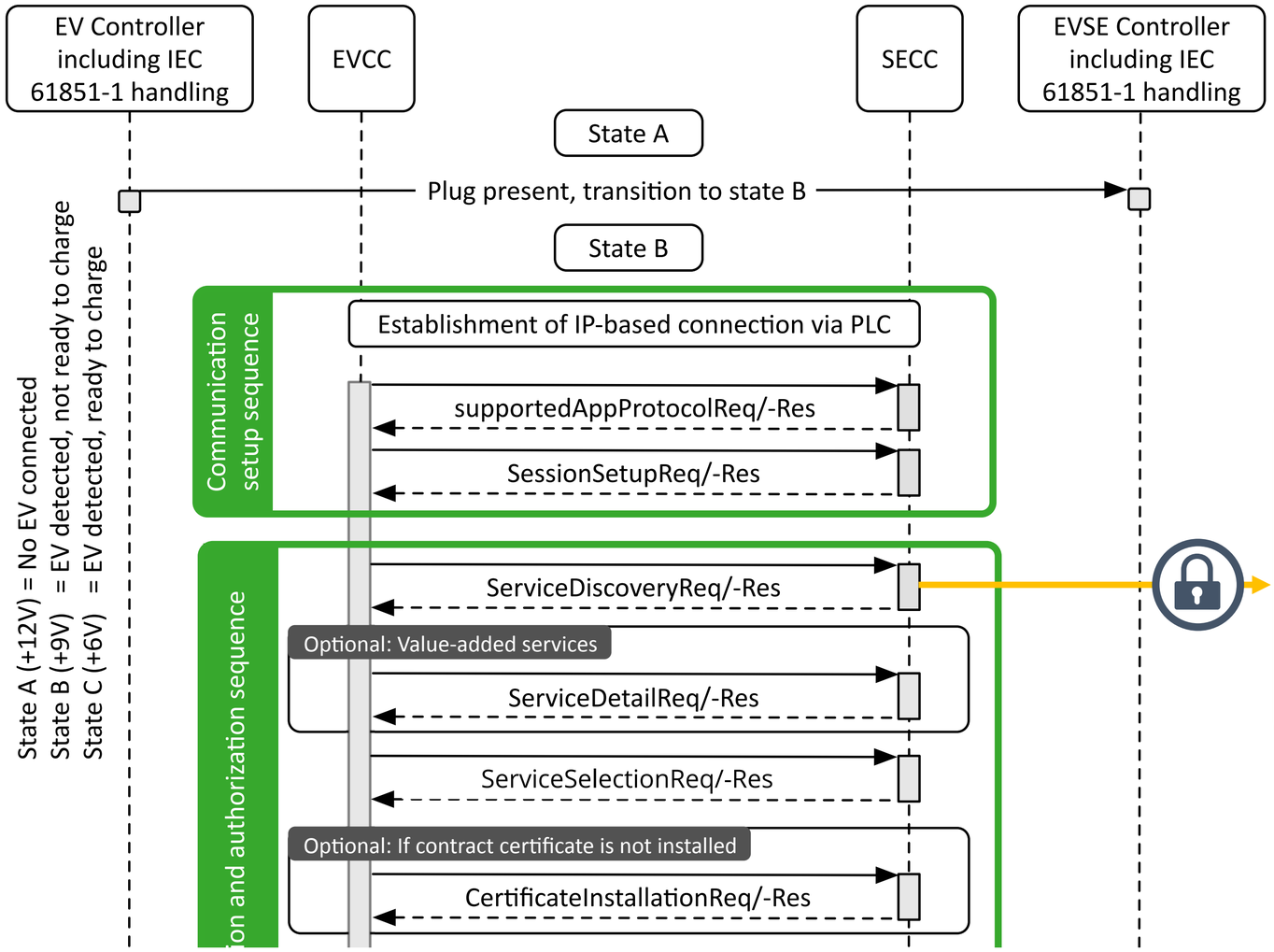
Four Steps to Enable Vehicle-to-Grid Support

1. Check for Available Charging Services



Source: ISO 15118 Manual

EV asks which **power transfer** and value-added services as well as **identification** services (EIM, Plug & Charge) the charging station offers

Charging services include one of

- **AC Charging** ❯ **Support Bidirectional Power Transfer (BPT)**
- **DC Charging** ❯ **Support Bidirectional Power Transfer (BPT)**
- WPT (Wireless Power Transfer)
- ACD (Automatic Connection Device)

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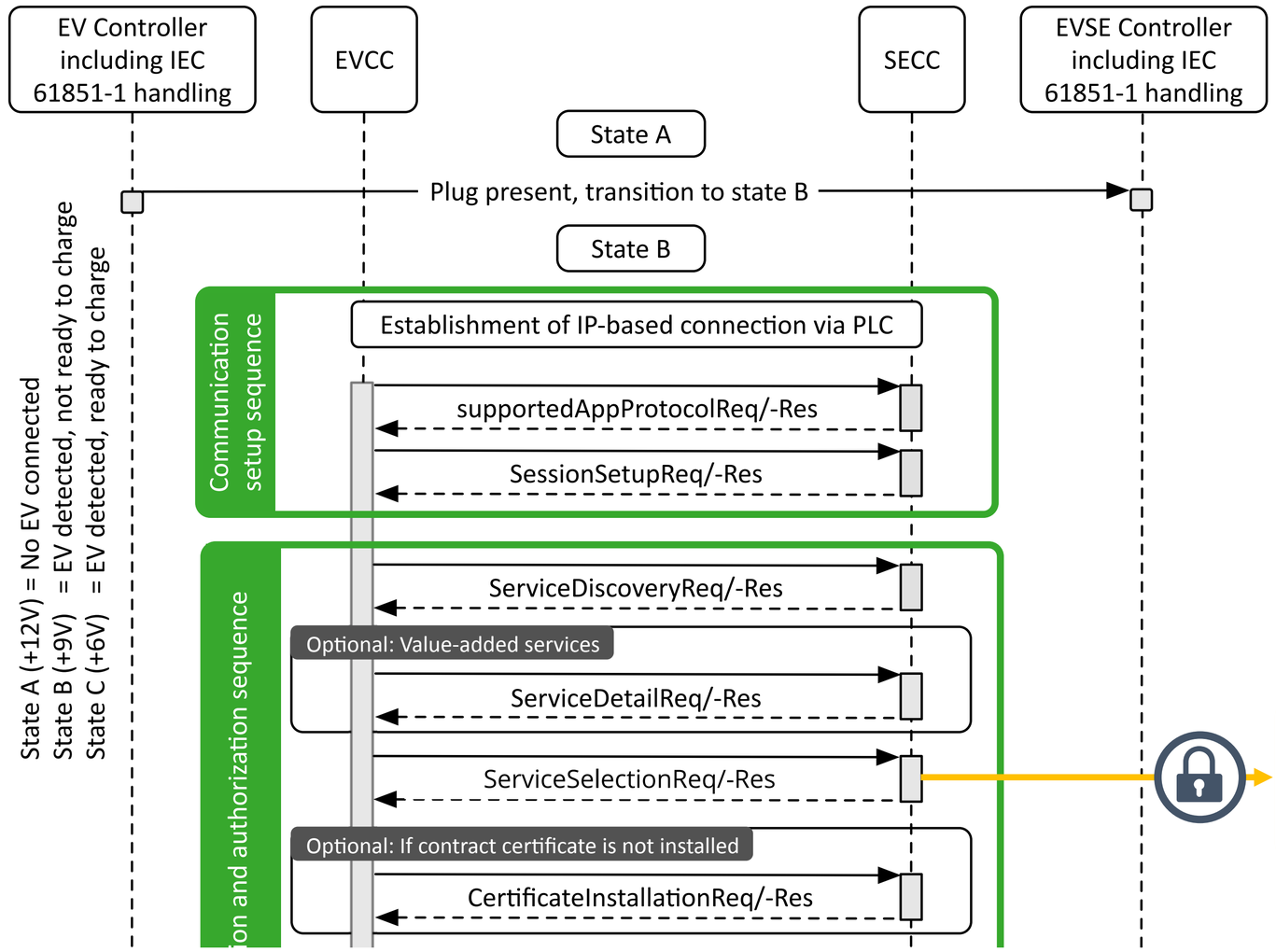

Source: ISO 15118 Manual

Assume:

EV chooses **AC** charging
with **Bidirectional** Power Transfer

EV tells charging station which identification service (EIM or Plug & Charge), power transfer service, and value-added services it will select

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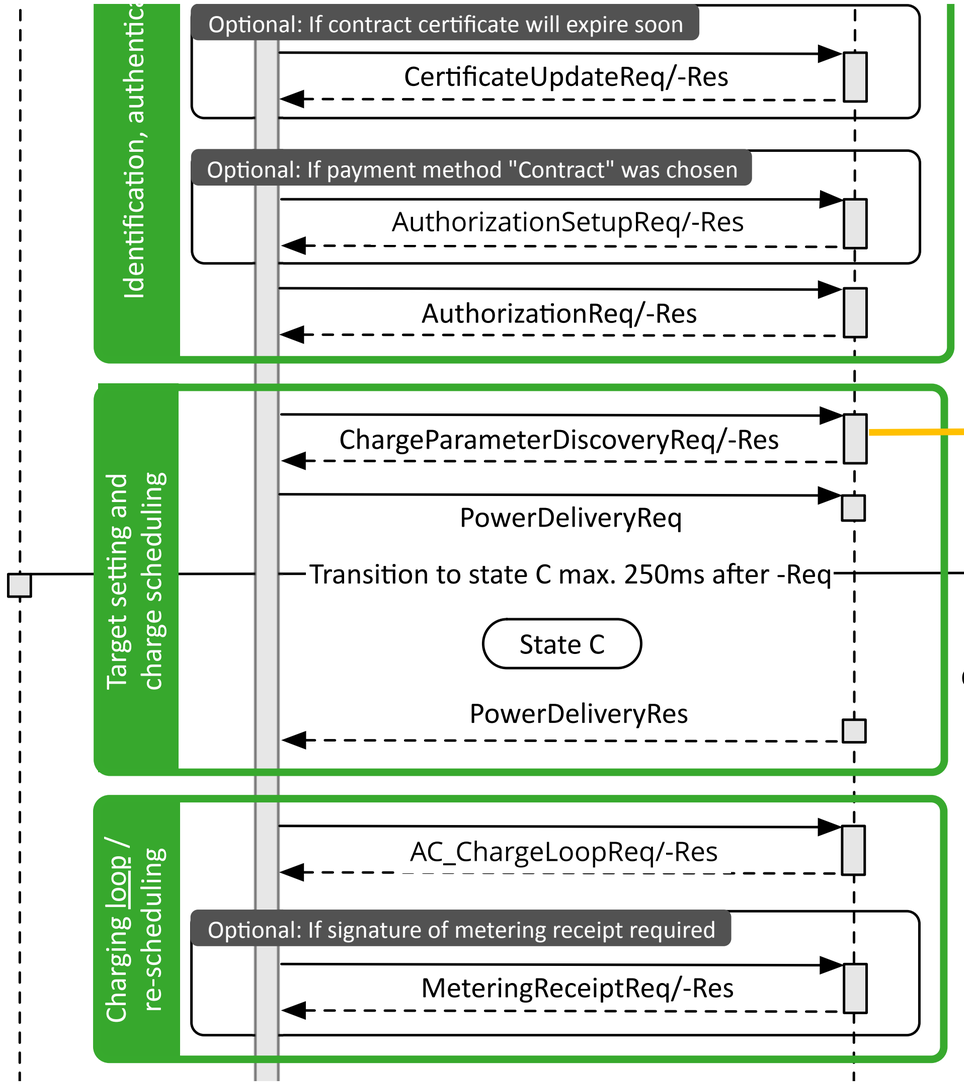
Four Steps to Enable Vehicle-to-Grid Support

2. Mutually Exchange Charging Limits



EV and charging station exchange mutual charging limits and a charging schedule

EV sends

- EVTarget**Energy**Request
- EVMaximum**Energy**Request
- EVMinimum**Energy**Request

- EVMaximum**Charge**Power
- EVMaximum**Charge**Current
- EVMinimum**Charge**Current
- EVMaximumVoltage

- EVMaximum**Discharge**Power
- EVMinimum**Discharge**Power
- EVMaximum**Discharge**Current
- EVMinimum**Discharge**Current

Source: ISO 15118 Manual

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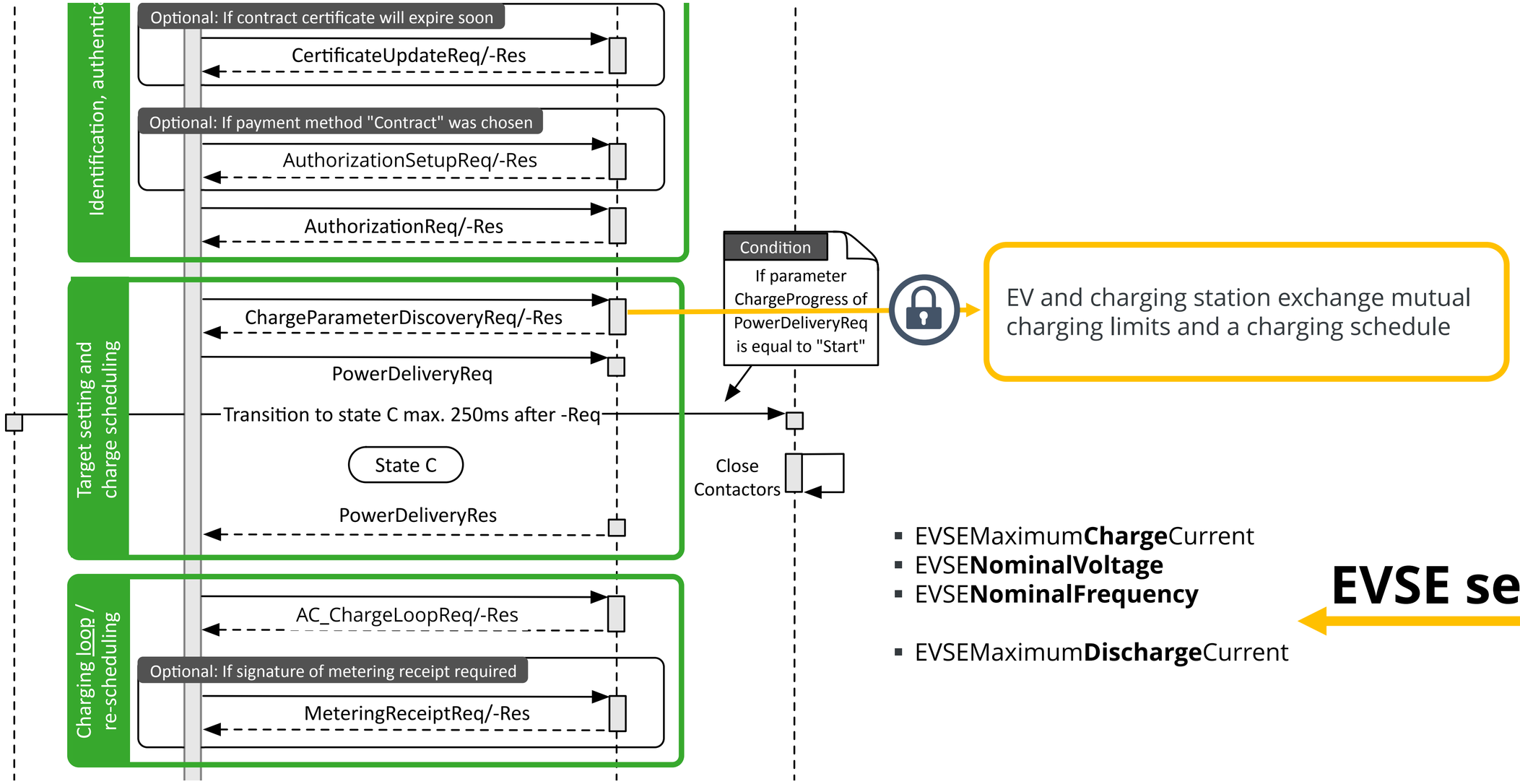

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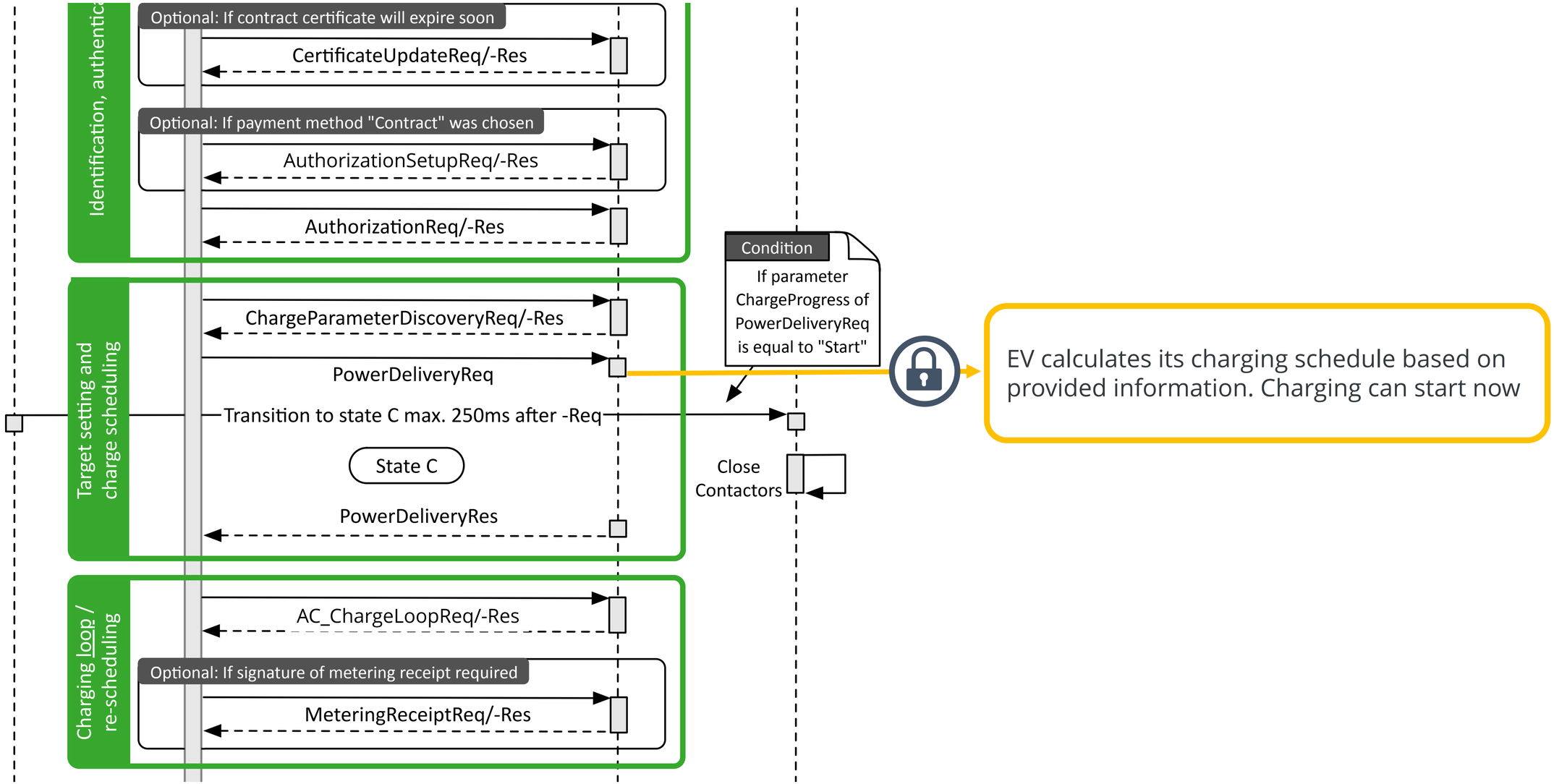
Four Steps to Enable Vehicle-to-Grid Support

3. Calculate and Send Power Profile to Charging Station



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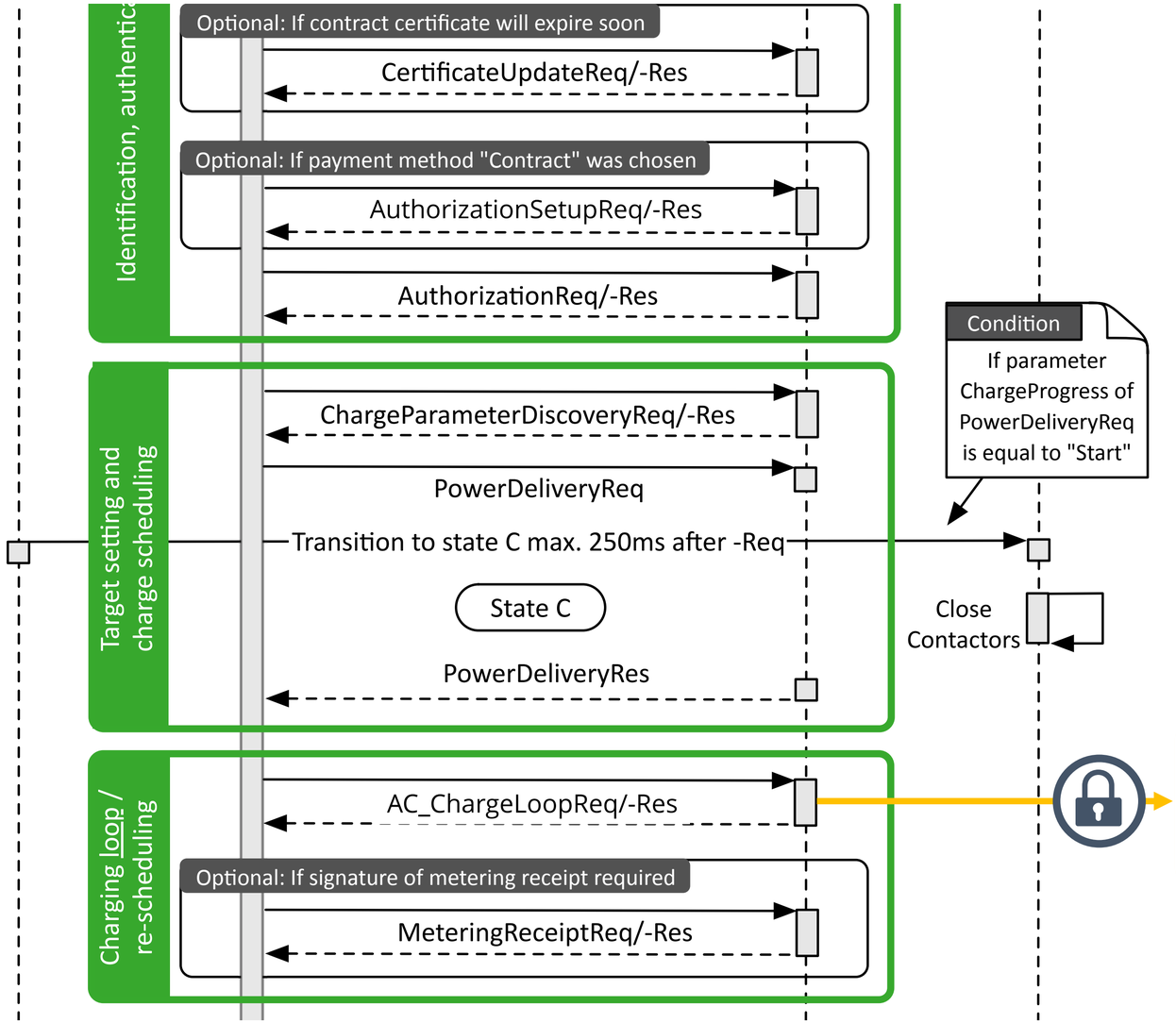
Four Steps to Enable Vehicle-to-Grid Support

4. Control the Charging Process in the Charging Loop



EV sends

- EVTarget**Energy**Request
- EVMaximum**Energy**Request
- EVMinimum**Energy**Request

- EVMaximum**Charge**Power
- EVMaximum**Charge**Current
- EVMinimum**Charge**Current

- EVMaximum**Discharge**Power
- EVMaximum**Discharge**Current
- EVMinimum**Discharge**Current

- EVPresent**ActivePower**
- EVPresent**ReactivePower**

Control messages during charging loop.
Renegotiation of charging schedule possible

Source: ISO 15118 Manual

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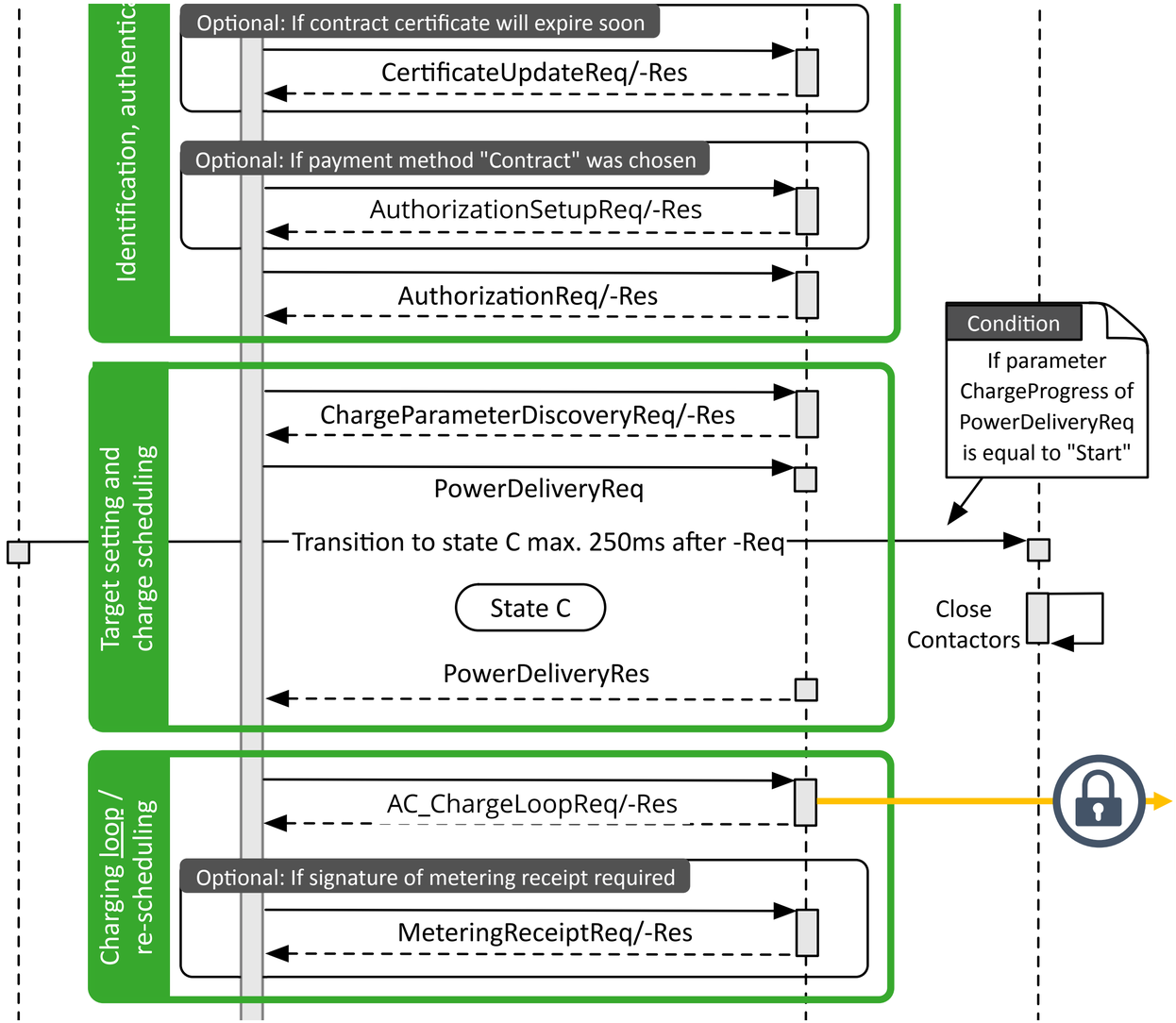
Four Steps to Enable Vehicle-to-Grid Support

4. Control the Charging Process in the Charging Loop



EVSE sends

- EVSETarget**Frequency**
- EVSETarget**ActivePower**
- EVSETarget**ReactivePower**

Control messages during charging loop.
Renegotiation of charging schedule possible

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When to Expect ISO 15118 EVs

- **BEVs with ISO 15118-2 with Plug & Charge**
  Audi E-tron (2019), BWM (2020/2021), Daimler EQC (2019), Porsche Taycan (2019), smart electric drive v3 (since 2017), VW ID (202x ??)

- **Daimler already sells smart electric drive** with ISO 15118 support for AC charging with Plug & Charge
  → See also press release „Convenient charging of electric vehicles without the need for a card or app“
  → Hubject provides PKI ecosystem based on VDE application guide VDE-AR-E 2802-100-1

- **Innogy SE** is pioneer on charging infrastructure side, but more an more EV charging solution providers (e.g. Ebee/Bender) gain momentum (see **Market Overview on ISO 15118-Compliant Products** => V2G Clarity Newsletter)

- Regular industry events to see state-of-the-art development (register at www.testing-symposium.net/, video at https://2019.charin-testival.org/home):
  → 13th Testing Symposium, **May 14 & 15, 2020 in Stuttgart (Germany),** hosted by Vector Informatik
  → 2nd CharIN Testival, **April 28 & 29, 2020, Newark (California, U.S.)** hosted by Lucid Motors

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Cyber Security Features

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Pillars of IT Security

The CIA Triad

C

CONFIDENTIALITY

The content of a message (plain text) shall only be readable by the intended recipient(s), but not by any unauthorized third parties.

✓

Secure exchange of information to calculate symmetric key achieved through ECDH

Symmetric encryption through AES-128-CBC cipher

I

INTEGRITY

An unauthorized modification of the sent message shall be avoided or at least be detected.

A

AUTHENTICITY

Assert that the communicating parties are really the persons or entities which they claim to be.

Asymmetric cryptosystem (public-key cryptography) and secure hashes needed (for creation and verification of digital signatures)

✓

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Hybrid Cryptosystems

Asymmetric

ECDH

Elliptic Curve
Diffie-Hellman

Secure way of calculating a symmetric key without explicitly **exchanging** that **symmetric key**

Symmetric key (128 bit)

Used with symmetric block cipher **AES-128-CBC**

Encrypts & decrypts

ISO 15118 messages during TLS session

Encrypt / decrypt messages between **EVCC** and **SECC** using TLS

Private key for contract certificate

MO encrypts private key for EV, **EV** decrypts and stores priv. key

ECDSA

Elliptic Curve
Digital Signature Algorithm

Create digital signatures

Verify digital signatures

Private key

Public key

Asymmetric ciphers require long key lengths compared to symmetric ciphers (computationally quite expensive), which is why **symmetric** ciphers are used for encrypting the communication.

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ISO 15118 Public-Key Infrastructure

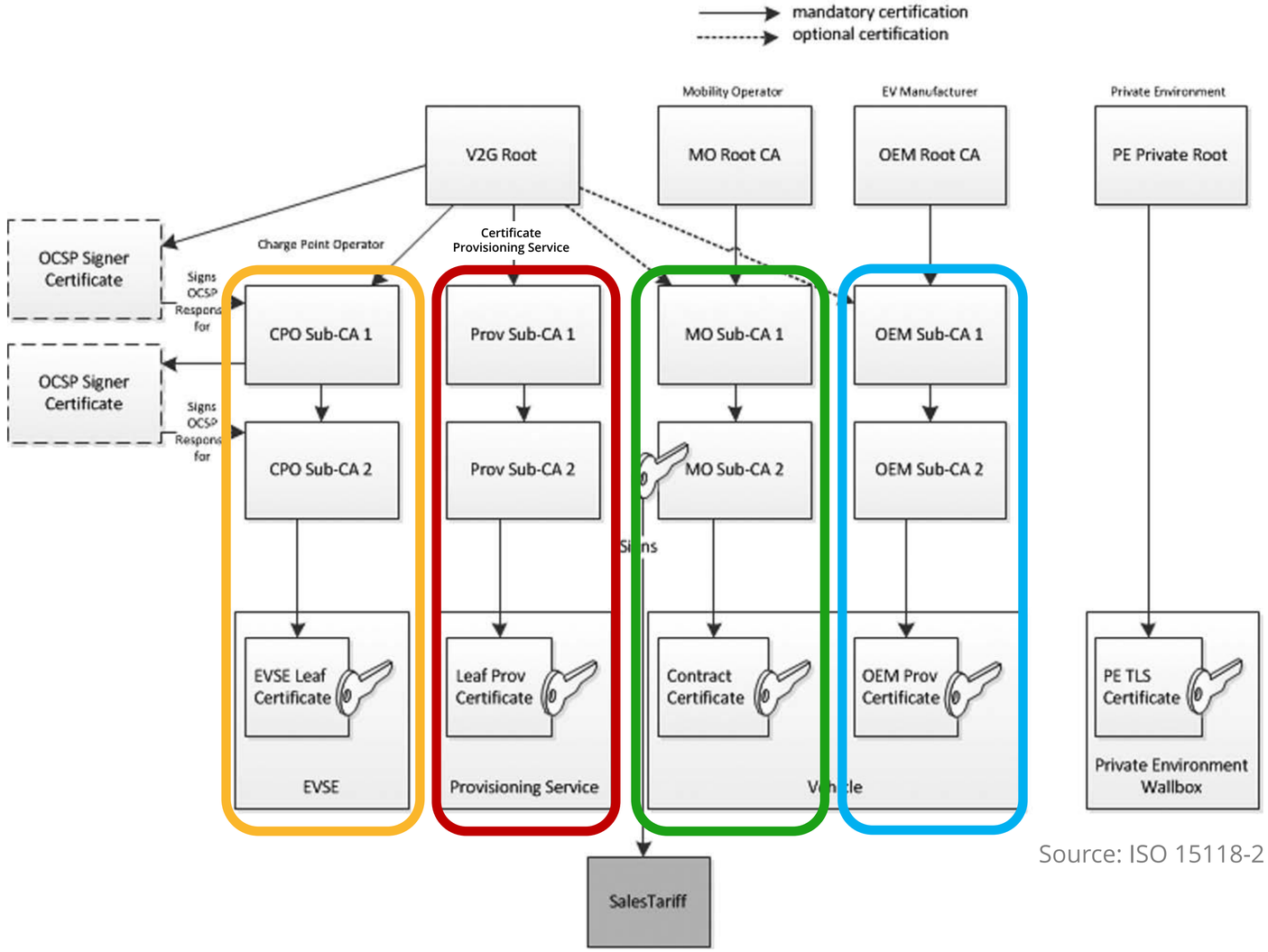
One PKI for each Plug & Charge market role

Charge Point Operator (CPO)
Operates and maintains the charging stations via its backend IT system

Certificate Provisioning Service (CPS)
Facilitates the installation of a new contract certificate for the EV through a digital signature

Mobility Operator (MO)
Provides a legal e-mobility contract and issues contract certificates associated with that legal contract

Car manufacturer (OEM)
Issues the unique OEM provisioning certificate needed to install a new contract certificate for Plug & Charge



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ISO 15118 Public-Key Infrastructure

Hierarchical levels in each PKI

Root Certificate Authorities (CAs)

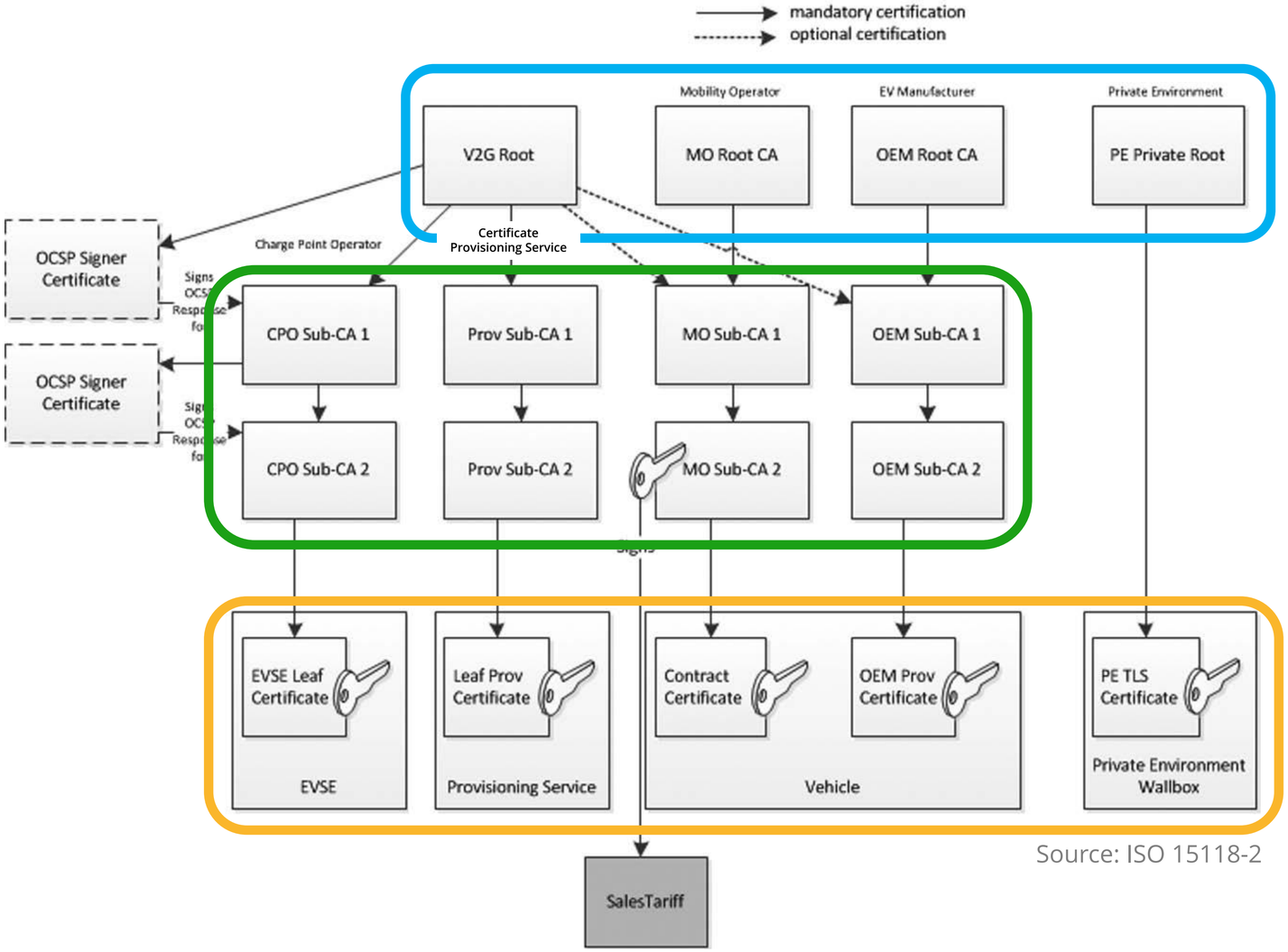
The **top-level trust anchors** that everyone must trust in. Issue **self-signed certificates** for themselves and certificates for sub-CAs

Subordinate CAs (Sub-CAs)

Issue certificates for either another **sub-CA** (sub-CA 1 issues for sub-CA 2) **or for a leaf certificate**. Min. one sub-CA is required, optionally two sub-CAs

Leaf certificates

The actual certificates **used for authentication.** For example: SECC leaf certificate, contract certificate, OEM prov. certificate



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Available Resources to Get Started with ISO 15118

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Market Overview on ISO 15118-Compliant Products

- **Register your ISO 15118-compliant product at** https://v2gclarity.typeform.com/to/gylK5Z
- Will be available to all subscribers of the V2G Clarity Newsletter (>> 1,600 subscribers)

May 2019

Market Overview of ISO 15118-Compliant Products

Company Name	Country	Product Name	Type of Product	Feature Set	Launch Date	Contact Information
Auto Motive Power (AMP)	USA	ampCCS, ampV2G and AMP Fast Charge Junction Box	EVCC, SECC	PnC, no-PnC, SLAC	2019-01-03	sales@automotivepower.com, kyle@automotivepower.com
Bender GmbH & Co. KG	DE	Bender Charge Controller Family	SECC	PnC, SLAC	2016-03-01	frank.mehling@bender.de
Bio	UKR	CCS charging stations	EVSE, SECC	no-PnC, SLAC	2019-09-01	bioautoua@ukr.net
Ebee Smart Technologies GmbH	DE	Ladepunkt Berlin	EVSE	PnC, SLAC	2016-03-01	Sales@ebee.berlin
Ensto	FIN	EVB, EVF and EVC - series	EVSE	PnC, SLAC	2018-01-01	eero.korhonen@ensto.com
GENIS KOREA Co., Ltd.	KR	SECC, EVCC, Testing System	EVCC, SECC, TS-EV, TS-EVSE	PnC, SLAC, wireless	2019-06-30	sales@genisev.com
Gridwiz Inc.	KR	PEPPERMINT, PEPPERMINT Plus, APPLEMINT	EVCC, SECC	PnC, no-PnC, SLAC	2014-01-01	lucy@gridwiz.com
Hubject	DE	Plug&Charge Trust Light, Plug&Charge Trust, Plug&Charge Management, Plug&Charge Ecosystem	V2G-Root-CA	PnC	2018-04-01	Barton.Sidles@hubject.com
in-tech smart charging GmbH (former I2SE)	DE	Charge Control C	SECC	PnC, SLAC	2018-10-01	antonio.krueger@in-tech.com
in-tech smart charging GmbH (former I2SE)	DE	Charge Control M	EVCC, SECC	PnC, SLAC	2018-04-01	antonio.krueger@in-tech.com

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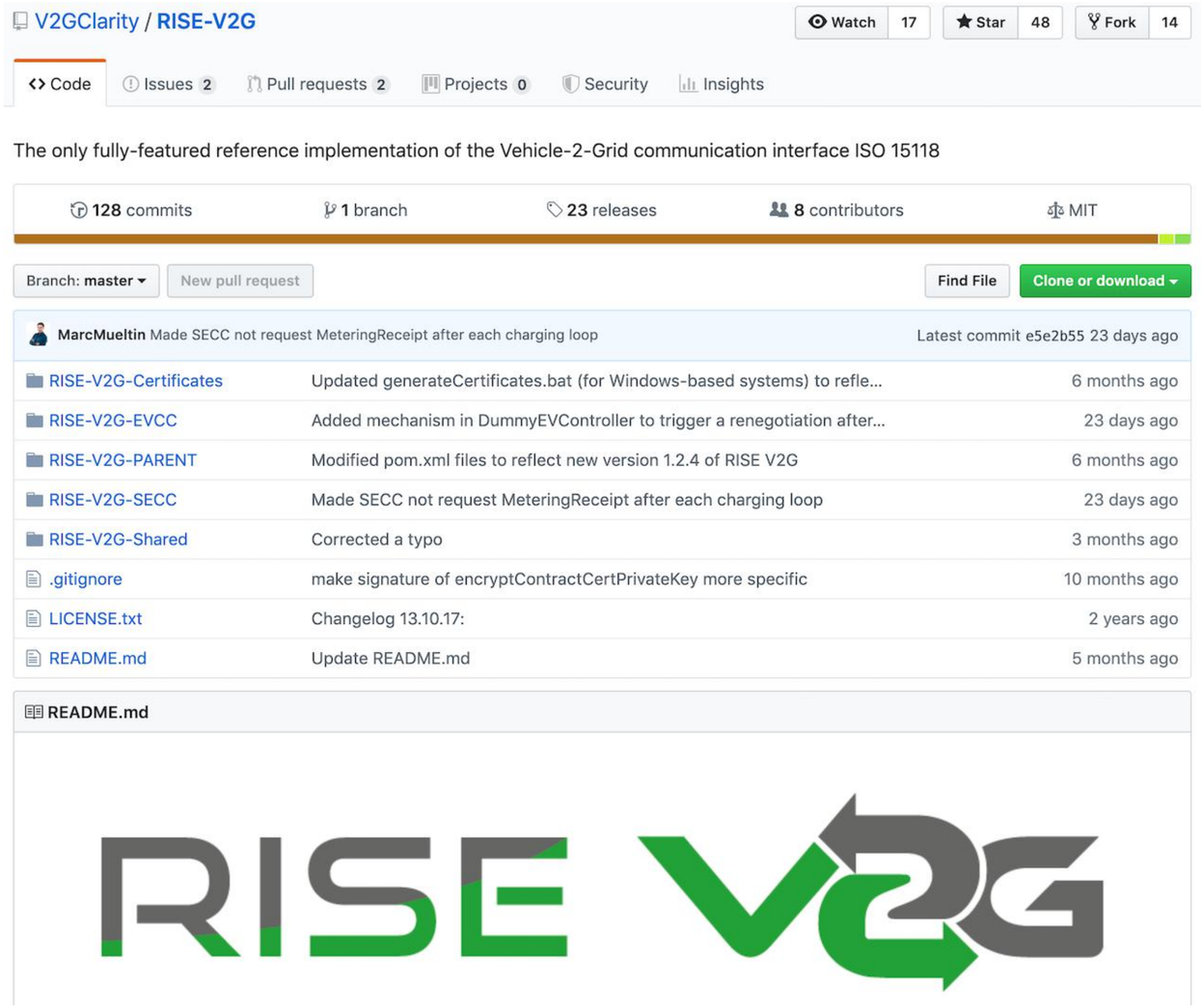
RISE V2G – ISO 15118 Open Source

github.com/V2GClarity/RISE-V2G

- Reference implementation of **ISO 15118-2** that **covers all features**
  - AC and DC charging
  - EIM and Plug & Charge
  - TLS and certificate handling
  - For both EV and charging station
  - Uses Exificient and OpenEXI
- Licensed under MIT
  → Can be used for commercial products
- Has been tested at all testing symposia so far; evolved as a highly appreciated solution by companies and research institutions worldwide

RISE V2G 2.0 will come with ISO 15118-20 – and stay open source



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Knowledge Base Articles

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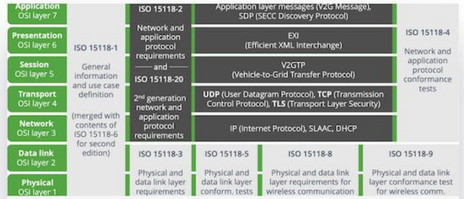
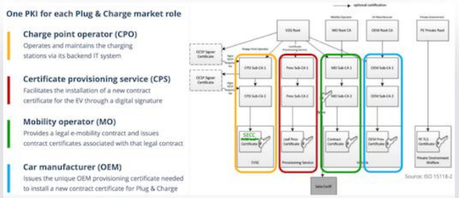


What Is ISO 15118?

Get to know one of the world's leading international electric vehicle standards

Read more



The Basics of Plug & Charge

ISO 15118's feature for a more user-convenient and secure way of charging electric vehicles

Read more

Keynote Speech on ISO 15118

A free, one-hour video introduction to the industry-approved EV charging standard.

View video

Vehicle-to-Grid Services

How electric vehicles help stabilize the electric grid by providing vehicle-to-grid (V2G) services

Read more

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v2g-clarity.com/iso15118-manual

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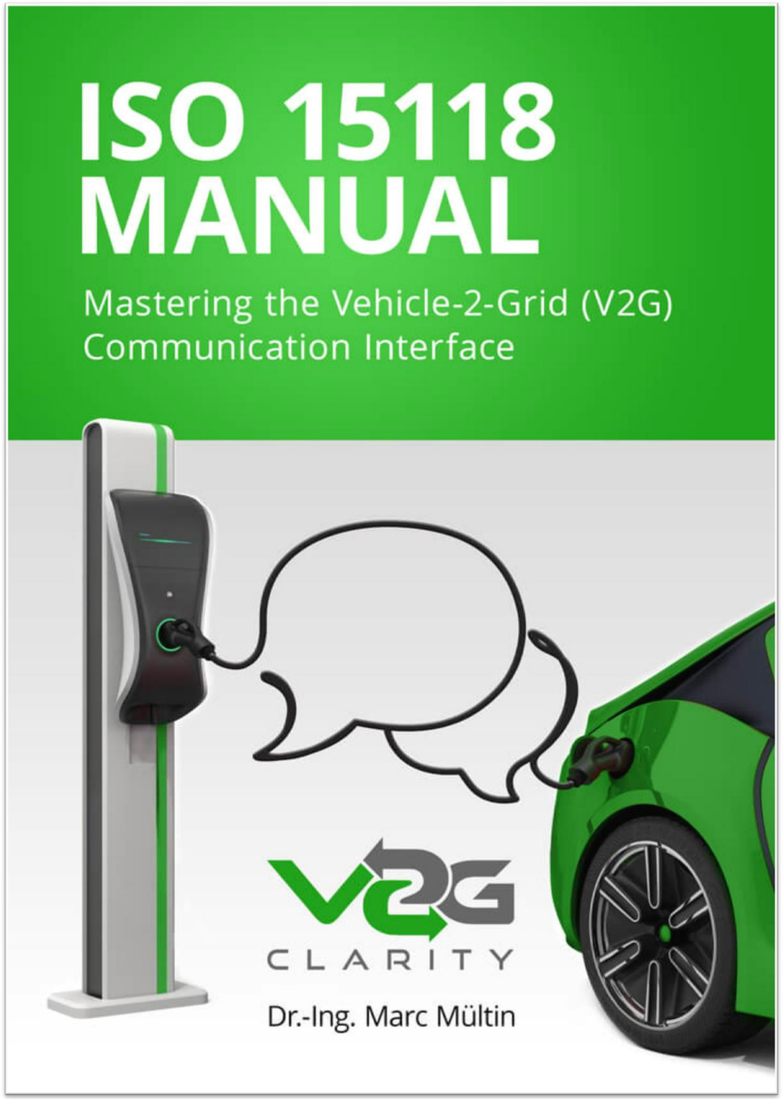

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Online Courses to Deepen Your ISO 15118 Expertise

- https://github.com/V2GClarity/RISE-V2G

- Online courses for in-depth guide through RISE V2G and ISO 15118

  Revolutionize Electric Vehicle Charging
  (RISE V2G Basics):
  https://courses.v2g-clarity.com/p/risev2g-basics/

  Master the Communication for Charging Electric Vehicles
  (RISE V2G Advanced)
  https://courses.v2g-clarity.com/p/risev2g-advanced1/

- Online course focusing on security-related topics, i.e. cryptographic foundations of Plug & Charge, TLS handshake, public key cryptography, etc.

  Data Security and Plug & Charge With ISO 15118
  https://courses.v2g-clarity.com/p/data-security-and-pnc-with-iso15118

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