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OCPP Interoperability: Democratized Future of Charging

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Executive Summary

The electric vehicle charging infrastructure grows exponentially, yet there is no consistent experience for EV drivers to charge their vehicles, which hinders the important EV mass market adoption.
The Open Charge Point Protocol (OCPP) landscape is the solution to this challenge as it provides standardization and open communication between EV infrastructure components. The interplay of the OCPP with open cross-functional communication standards boosters driver experience on the one hand, while the charging station itself is integrated into a renewable energy ecosystem.
This paper presents a deep dive into the combination of the OCPP with the OpenADR protocol, the Open Smart Charging Protocol (OSCP), the ISO 15118, and eRoaming protocols to explore possibilities and limitations. Furthermore, we suggest LoRa communication as an alternative to IP-based communication for deep-in building applications. Hence, this paper reveals the next important steps towards a successful EV mass market transition powered by user-friendliness and green energy.

1 Introduction

A user-friendly and reliable electric vehicle (EV) infrastructure drives tomorrow's green and successful automotive ecosystem, critical to achieve the net-zero emissions target by 2050 [1]. However, a recent survey of EV users reported substantial frustration with chargers being too slow, too crowded, or not operable [1, 2]. In combination with range anxiety during long distance travel [3], a skeptical attitude toward EVs has evolved, which hinders a commitment to private or commercial EV ownership and prevents a profitable EV mass market adoption.
Interoperability within the EV infrastructure provides the solution to that challenge by nurturing a consistent and familiar EV driver experience powered by a reliable and green 'Distributed Energy Resources' (DER) energy ecosystem (Figure 1).

Interoperability in this case is two dimensional:

(1) consumer facing and
(2) backend systems facing.

Consumer facing interoperability includes physical access of a charging station (CS), universal or automated payment methods at the CS or nearby, digital and capacity-based availability of a CS, and a 'one-matches-all' coupler hardware, that is consistent with current consumer re-fueling expectations.
Backend facing interoperability encompasses standardized or de facto technical details, protocols, and operations to accomplish consumer facing interoperability. Backend interoperability allows for standardized communication between CSs and their respective central management system (CMS), as well as uniform data exchange between

CMSs and third-party backends, such as e-Mobility Service Providers (eMSPs) and Capacity Providers (CP) (counting utilities, distributed systems operators (DSOs), and cloud-based energy management systems (EMSs)).

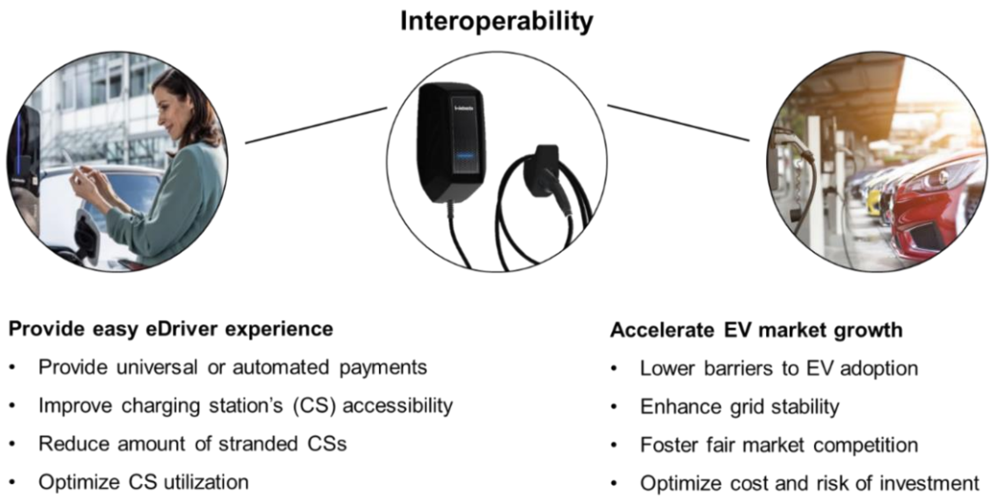

Figure 1: Interoperability within the EV infrastructure provides a user-friendly eDriver experience and accelerates the EV market growth.

It is with this consideration, that Webasto wallbox systems utilize the major de facto open CS-CMS communication protocol in the US, the Open Charge Point Protocol (OCPP). Webasto charging systems provide an interoperable, flexible, and expandable infrastructure platform, that is capable of interconnecting with a broad range of eMSPs, charging station operators (CSOs), OEMs, and CPs, fostering critical consumer interoperability and friendliness (Figure 2, left).

Most application protocols for backend regulation, such as the OCPP, require IP-based communication. For deep-in building charging technologies, that demand low bandwidth and long-range (for example the transfer of battery status data in warehouses) a LoRa connectivity shall provide a great alternative to Wi-Fi, BLE, and Cellular. LoRa facilitates a long-range communication up to 10 miles and consumes ultra-low power [4]. Via a LoRa gateway and encryption techniques, battery data can then securely be transferred to the backend system (Figure 2, right).

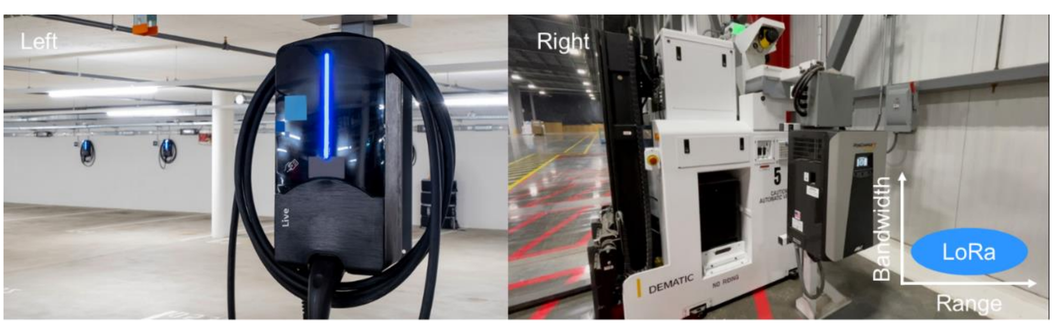

Figure 2: Left: A Webasto wallbox is connected to a cloud-based EMS enabling capacity-based smart charging. Right: Deep-in building application of Webasto industrial chargers facilitating LoRa [5].

This paper focuses on the IP-based OCPP landscape and the interplay of the OCPP with cross-functional open standards to booster driver experience on the one hand, while the CS itself is integrated into a modern energy ecosystem. We perform a deep dive into the combination of the OCPP with the OpenADR protocol, the Open Smart Charging Protocol (OSCP), the ISO 15118, and eRoaming protocols to eventually discuss factors for success, possibilities, and limitations of open standards (Figure 3). As such this paper reveals the next important steps towards a successful EV market transition powered by user-friendliness and green energy.

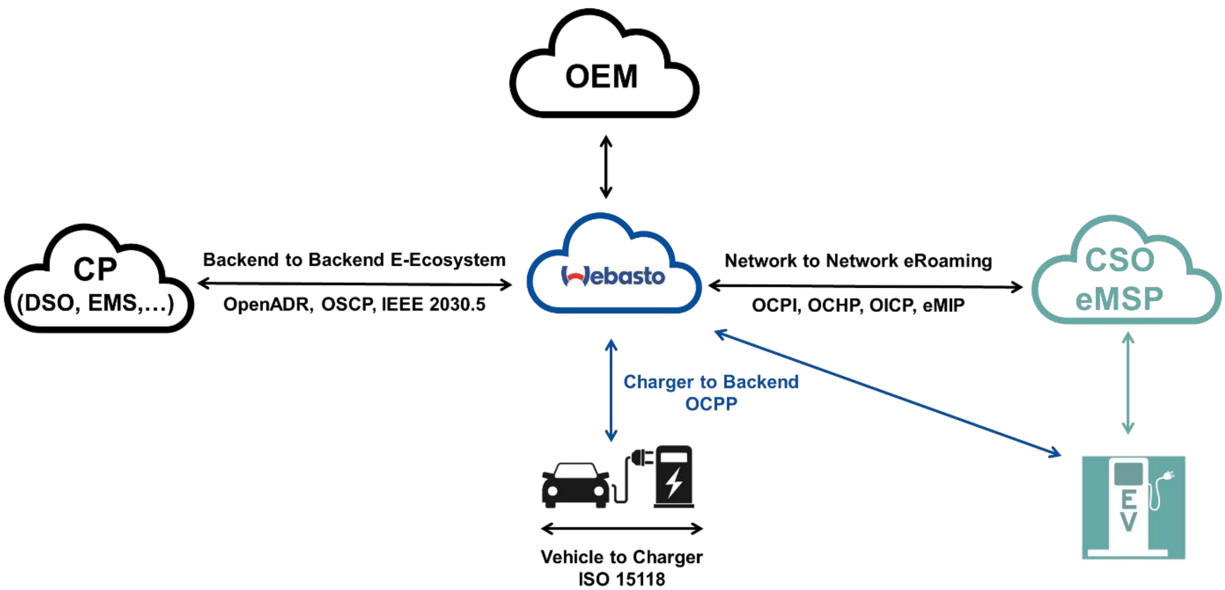

Figure 2: The OCPP is the major open de facto communication protocol for CS-CMS communication. Cross-functional backend communication is multi-faceted and facilitates different protocols for diverse needs. For the communication between capacity providers (CP) and central management systems, protocols such as the OpenADR protocol or the Open Smart Charging Protocol (OSCP) are in place. For eRoaming, that requires CMS to CSO/eMSPs backend communication, the Open Charge Point Interface (OCPI) protocol, the Open Clearing House Protocol (OCHP), the eMobility Interoperation Protocol (eMIP), and the Open InterCharge Protocol (OICP) are dominantly used, serving hub-based or bilateral eRoaming structures. The ISO 15118 is an international standard series, that contains specifications for secure, local, and bidirectional communication between EV and CSs.

2 OCPP, OpenADR protocol, and OSCP

The principal de facto open protocol for unified, IP-based CS-CMS communication in the US is the Open Charge Point Protocol (OCPP). The combination of the OCPP with the Open Automated Demand Response (OpenADR) protocol or the Open Smart Charging Protocol (OSCP) turns a CS into a flexibility provider, that can react on changes in Demand-Response (DR) within a DER energy ecosystem. This converts an uninformed charging process into a smart system, that can throttle or postpone charging based on currently and locally available capacity.

OCPP

Developed in 2009 by the E-Laad Foundation (now ElaadNL) and maintained by the Open Charge Alliance in Arnhem, NL, the IP-based OCPP is the major de facto communication protocol between CS and CMS (Figure 4). The OCPP enables any CMS to connect with any CS, regardless the vendor, if the CMS and the CS are compliant with the same OCPP version [6].

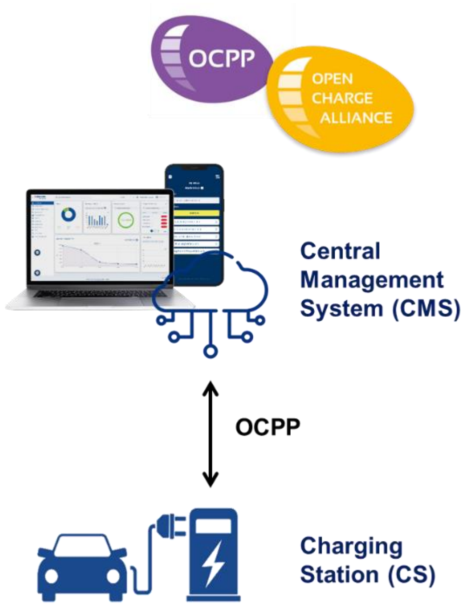

Figure 4: The OCPP is the major de facto open communication protocol between a CS and its CMS.

The latest version of the OCPP (released March 2020, v. 2.0.1) serves Level 2 and DCFC charging techniques (GB/T, CHAdeMO, and CCS). The application protocol enables functionalities such as availability of chargers, payments, reservation, smart charging, certificate management, and many more [6]. Through the openness of the protocol new features and improvements can be continuously added.

OCPP interoperability within different EV infrastructure components paves the way for a more cohesive and integrated charging network, enhancing eDriver experience and fostering less stranded assets. In addition, the fact, that a charging station operator (CSO) has the flexibility to purchase equipment from multiple vendors ("mix and match") allows the CSO to be manufacturer agnostic and fuels a fair market competition in the industry.

OCPP and OpenADR

The production of renewable energy has become more and more decentralized with individual households and businesses generating their own energy through photovoltaics, wind turbines, and other types of DERs, like electric energy storage (EES) systems. A such there is a huge desire for these diverse systems to communicate and work together effectively [7,8].
Energy suppliers worldwide use the OpenADR standard to enable bi-directional IP-based communication between capacity providers - including utilities or distribution systems operators (DSOs) - and end devices to coordinate their responses to changes in energy supply/demand [9]. The OpenADR protocol is maintained by the

OpenADR Alliance and encompasses services such as event messages, reports, registration services, as well as availability schedules for dynamic price- and capacity-based programs [10].

The combination of OCPP and OpenADR equips charging stations with the capability to quickly react on locally and currently available DER grid capacity and makes the charging station thus flexible and smart (Figure 5). While the OpenADR protocol standardizes the messaging and DR information exchange between a CP's backend and the CMS, the OCPP functionalities initiate the actions required from the CS. Such reactions can be postponing a charging process, consider priority charging, and optimizing charging schedules [10]. On the consumer side, the interplay of the OCPP and the OpenADR protocol saves cost per consumed energy unit (kWh) while maximizing the amount of renewable energy used for EV charging.

Practically, an OCPP central server can register with the OpenADR Virtual Top Node server as an OpenADR Virtual End Node and can include all participating charging stations into the dynamic electricity system [11].

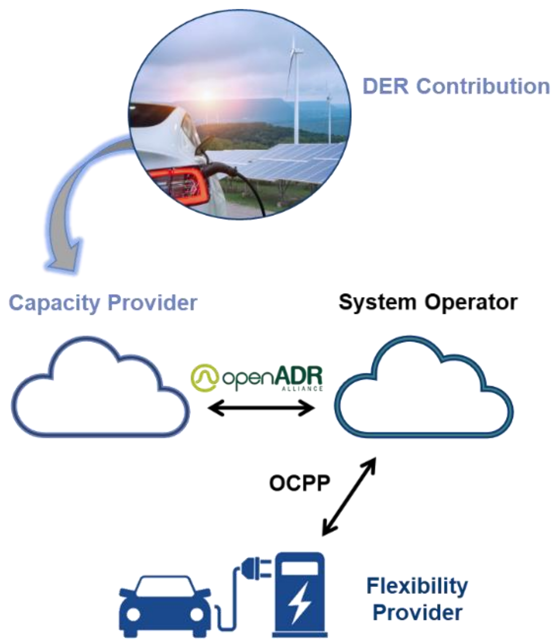

Figure 5: The line-up of the OCPP with the OpenADR standard turns a CS into an efficient flexibility provider integrated into a green DER energy ecosystem.

OCPP and OSCP

In a similar fashion, the Open Smart Charging Protocol or short OSCP was established in October 2020 by the Open Charge Alliance [13] and takes the integration of EVs into larger, dynamic, and flexible energy ecosystems (including photovoltaics, stationary batteries, heat pumps, etc.) into consideration. The OSCP standardizes the communication between a capacity provider, which can be a cloud-based EMS for example, and the CMS, while taking a 24-hour prediction of the local available grid capacity into consideration (compare Figure 5). Such communication capabilities of a CS with the grid turns a CSO into a flexibility provider, capable of matching charging profiles within local capacity trendlines, e.g., capacity-based smart charging (compare Figure 6). In addition, the operator can request the most optimal EV charging energy demand, without overloading the grid.

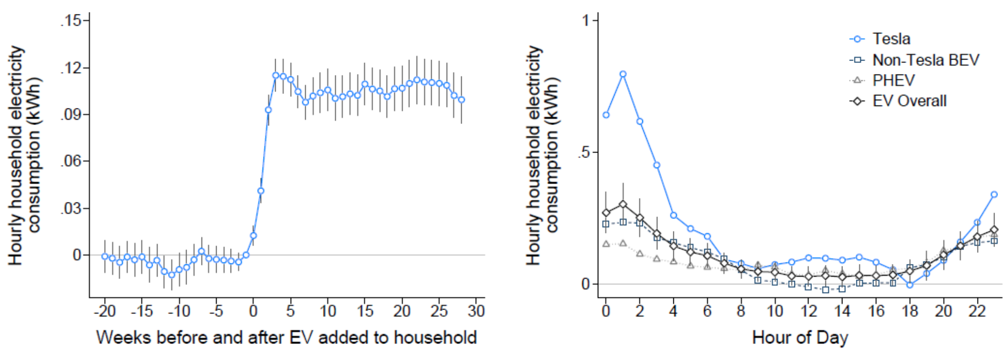

Figure 3: Impacts of EV adoption on household electricity. Left: EV adoption increases household electricity consumption by 0.12 kWh hourly or ca. 3kWh per day. Right: Effects are concentrated between 10 PM and 6 PM, including heterogeneity for certain EV types [12]. Services, such as capacity-based smart charging or load balancing help optimizing energy consumption and prices.

3 OCPP and ISO 15118

The ISO 15118, Plug and Charge, boosts the driver experience by providing a local and automated payment process upon only plugging the charger into the EV. No user interaction is needed. In addition, the combination of the OCPP with OpenADR and the ISO 15118, Vehicle to Grid, allows the conversion of an EV into a mobile electric energy storage (EES) unit, that can actively supply (green) energy back into the grid in times of high demand or emergency, promoting a stable and reliable DER grid ecosystem.

ISO 15118

The ISO 15118 Road vehicles - Vehicle to grid communication interface is an international standard series, which contains specifications for bidirectional communication between EVs and CSs [14]. Among others, the standard defines following two use cases:

- Plug and Charge (PnC) i.e., automatic authorization and payment upon connecting an EVSE with the car.
- Vehicle to Grid (V2G) i.e., EV can supply energy back to the grid.

ISO 15118 Plug and Charge (PnC)

The ISO 15118 PnC use case provides an automated charging and payment process upon only plugging the charger into the EV. The charging authentication and authorization is accomplished using digital certificates that are exchanged locally between the EV and the CS [15] (Figure 7). (For the billing part a backend connection to the CSO or eMSP may be required in case parties want to access and process billing information.) The digital certificates are stored in the onboard system of the EV and of the CS, respectively. The EV's certificate is called identity certificate, that is used to authenticate the EV to the CS. Similar, the CS's digital contract certificate is used to authenticate the CS to the EV. By exchanging these two certificates, the EV and the CS can securely communicate and negotiate charging parameters, charging rates, and billing details agreed upon by the EV owner and the CSO [14]. The certificates are signed by a third-party certificate authority, and in combination with encryption methods, ISO 15118 ensures that the EV-CS communication is secure and that user's contract data are protected [16].

Certificate field	Description
Version	Version of certificate (for 15118 shall be v3 = 0x2)
Serial number	Unique number of certificate (within the domain of the issuer)
Signature algorithm	Used signature algorithm
Issuer	Entity, who has issued and signed the certificate
Validity period	Time period, in which the certificate is valid
Subject	Entity, to which the certificate is issued
Public key	Public key corresponding to a private key
Issuer UID	Optional issuer unique identifier
Subject UID	Optional subject unique identifier
Extensions	Optional (see Table 2)
Signature	Signature of the certificate generated by the issuer

Figure 4: Basic certificate fields for a typical X.509v3-certificate as used in ISO 15118 [14].

ISO 15118 Vehicle to Grid (V2G)

Electrical energy storage (EES) is one of the most effective support systems for balancing a green and dynamic DER grid [8]. EV traction batteries are excellent DR resources, that can store about 30 – 50 kWh electrical energy [19], while an average household in the US consumes 30 kWh electrical energy per day [20]. The ISO 15118 V2G use case allows bringing back green electrical energy from the EV's traction battery (originating from photovoltaics or wind power for example) to the grid (Figure 8) [14]. That energy can be used to power homes and businesses during peak demand periods, during emergencies, or when renewable energy sources are not active. In addition, private individuals can generate an extra income stream by providing green power to the grid, reducing the cost of ownership of the vehicle, while commercial fleet operators can create additional revenue with their EVs when not in use.

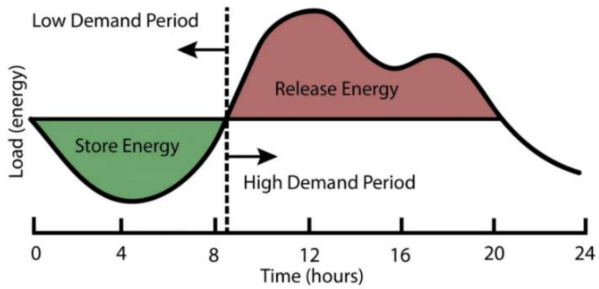

Figure 5: Electrical Energy Storage (EES) refers to the process of converting electrical energy into a stored form that can later be converted back into electrical energy when needed [8].

How it works: Once an EV is plugged into the charging station, the EV and the CS authenticate each other exchanging their identity and contract certificate, respectively. In addition, the EV communicates with the grid to determine the best discharging schedule based on driver relevant information, charging station response, and grid feedback (which also allows load leveling considering multiple EVs to be charged). To that aim a CS needs to be able to support the bidirectional data transfer and electricity flow between the EV and the grid. This can be a technically capable CS, e.g., including a bidirectional AC/DC converter, that is connected to an OCPP server and cross-linked through OpenADR/OSCP communication to the backend of a capacity provider/EMS (Figure 9). Once the discharging process is completed, the car and the CS exchange final information, including billing details and supplied energy [14].

Figure 9: The OCPP and ISO 15118 – Vehicle to Grid (V2G) turn an EV into a mobile and green EES, that can contribute energy to the grid in times of high demand or to generate an additional financial income stream.

For V2G many different parties, for example utilities, CSOs, eMSPs, or OEMs, participate and access hardware which requires seamless communication across multi-functional disciplines [21]. In addition, the data that is exchanged is very sensitive and contains payment and utility information. If not executed properly, departure of vehicles could be delayed, or utilities could charge penalties of an expected energy contribution to the grid not being executed. As such, it is very important to achieve the best possible backend interoperability and security by utilizing the same established backend systems standardization protocols.

4 eRoaming: "Charge anywhere"

The concept behind eRoaming is that a driver can "charge anywhere" and pay hassle-free across multiple CS networks using one single mobile app. This requires the seamless integration of a CS CMS into a hub-based or bilateral eRoaming platform, which provides a specific open communication protocol to this aim. Leading eRoaming hubs are "e-clearing.net", "GIREVE", and "Hubject", while the "EVRoaming Foundation" supports bilateral webbing and hybrid eRoaming with the hubs e-clearing.net and GIREVE.

Bilateral and Hybrid eRoaming

The non-profit EVRoaming Foundation maintains the free and independent Open Charge Point Interface (OCPI) protocol to join their network [22, 23] (Figure 10). Members of the global foundation are Chargepoint, Google Maps, Last Mile Solutions, Freshmile, and more. The OCPI protocol supports bilateral as well as hub-based roaming, for example with the European roaming hubs GIREVE [24] and e-clearing.net [25]. As such, the OCPI supports hybrid eRoaming network structures globally. Service functionalities of the OCPI protocol include authorization, reservation, provide tariff information, billing, real-time session information, etc. [22].

Hub-based eRoaming

The largest hub-based eRoaming structure is Hubject [26]. The network originates from a Joint Venture between BMW, Bosch, EnBW, Enel X, Mercedes Benz, Innogy, Siemens, and Volkswagen and is present around the globe, including US, Europe, and China. The roaming hub encompasses more than 300,000 CSs leading to a global user base of more than 10M drivers. To connect a CMS to the Hubject network the Open InterCharge Protocol (OICP) is required (Figure 10).
GIREVE [27] and e-clearing.net [25] are two large European eRoaming hubs, maintaining their respective eRoaming networking protocol, the eMobility Interoperation Protocol (eMIP) and the Open Clearing House Protocol (OCHP), respectively. Both hubs also support the EVRoaming Foundation's protocol OCPI, which allows OCPI supporters peer to peer eRoaming networking as well as hub network relations to GIREVE and e-clearing.net (Figure 10).

Comparison hub-based and bilateral eRoaming

In bilateral agreements, such as the OCPI protocol, network providers and manufacturers sign peer-to-peer agreements to create a web of interoperable CSs. This can take time and resources to set up and maintain a series of bilateral agreements and potentially introduce complications. It is also more restrictive for smaller players to enter the market. In central hubs and protocols such as the OICP (Hubject), eMIP (GIREVE), and OCHP (e-clearing.net) charging networks can join a central hub. The platform providers typically charge a fee for membership, which can potentially be re-directed to the driver. However, it is easy for new and smaller players to enter the market. No matter the networking structure, eRoaming platforms are crucial to accelerate the market for EV drivers and improve customer facing interoperability services [28].

	EVRoaming Foundation Realising cross-border charging		
	Peer to Peer Networking / Hybrid with Hubs		
	Freshmile, Chargepoint, Google Maps, Last Mile Solutions, NKL (global)		
	Open Charge Point Interface (OCPI 3.0)		
	Gireve	e-clearing.net	HUBJECT
Type	Hub	Hub	Hub
Players	Renault, CNR, la Caisse des Dépôts, EDF et Enedis	Smartlab, ELaadNL	BMW Group, Bosch, EnBW, Enel X, Mercedes-Benz, innogy, Siemens, Volkswagen Group
# of stations	>150k	>150k	>300k
# of active users	2M+	2M+	10M+
# of countries	20 (EU)	25 (EU)	52 (global)
Comm. Protocols	eMobility Interoperation Protocol (eMIP 1.0.14), Open Charge Point Interface Protocol (OCPI 3.0)	Open Clearing House Protocol (OCHP 1.4), Open Charge Point Interface Protocol (OCPI 3.0)	Open InterCharge Protocol (OICP), Open Plug&Charge Protocol (OPCP 1.0.0)

Figure 6: Overview major eRoaming Platforms.

5 Discussion and Outlook

We have shown how the interplay of the OCPP platform with open, cross-functional communication standards, such as OpenADR, ISO 15118, or eRoaming protocols, can solve recently reported substantial frustration with chargers being too slow, too crowded, or not being operable. OCPP interoperability imbedded within the EV infrastructure network provides a solution that fosters a consistent and familiar driver experience, while being powered by a reliable, smart, and green DER/DR energy ecosystem.

The OCPP landscape relies mostly on open-source development of communication protocols in the spirit of shared responsibility for a quality EV charging infrastructure. As such, open-source application protocols can provide content that is more correct and reliable than proprietary implementations [9]. Furthermore, OCPP interoperability enables standardized data sharing and diagnostics. This allows consumers/eMSPs to analyze charger and energy usage easily, while CSOs can increase charger utilization and minimize failure. Standardized data sharing also supports the development of new energy services and business models such as virtual power plants (VPP) and peer-to-peer energy trading forms. Databases, e.g., Alternative Fuels Data Center (DOE), can also display CS locations and CS availability across the US fostering CS access and operability information [29].

Global Consortia of public and private EV infrastructure leaders, such as the Open Charge Alliance, nurture the development, update, and adaption of international open communication protocols to standardize the EV charging industry and energy ecosystem. The success of a protocol is driven by market dynamics and stakeholder acceptance, rather than a regulated top-down decision by a singular authority. The Biden administration just recently announced "its latest set of actions aimed at creating a convenient, reliable and Made-in-America electric vehicle (EV) charging network so that the great American road trip can be electrified" [1].We are sure that OCPP interoperability will be in charge.

Acknowledgements

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Presenter Biography

Silke Kirchner received her Ph.D. in Physics with a focus on Nanophotonics at the Ludwig-Maximilian-University in Munich, Germany. She became a Postdoctoral Researcher at the Rice University in Houston, Texas and the California Institute of Technology (Caltech) in Pasadena, California, where she was part of the Joint Center for Artificial Photosynthesis (JCAP) and devoted her research to Nanophotonics for a Closed Carbon Cycle. As of 2018 Silke is a Product Manager for Digital Solutions in the Automotive Industry. She has taken active part in several automotive standardization forums, such as the International Committee for Display Metrology (ICDM) and the German Flat Panel Forum (DFF) to help define OEM specifications for the quality control of display solutions in the automotive interior.