Integration of Communication Protocols for Electric Vehicle Charging: Functionality and Integration

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Abstract: - EV charging stations are a critical piece of infrastructure to accelerate the transition to green and clean technologies. In recent years, the number of charging stations has grown significantly. This leads to the emergence of new problems and challenges for society, such as the management of charging processes, capacity balancing, and extended access. In this study, the basic concepts regarding standards and protocols for managing charging stations and capacities are presented. Over the years, the protocols have evolved and currently provide a variety of functionalities such as remote access, status tracking, station, and capacity control. The knowledge and development of these protocols will support easier and more adaptive use of charging stations. In addition, the current challenges that should be solved in the coming years are presented. They are related to the improvement of remote access, power balance, construction of hybrid systems of energy sources, and development of management information systems for management.

Key-Words: - electric vehicles, infrastructure, communication protocols, OCPP, OpenADR.

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1 Introduction

The proliferation of electric vehicle (EV) infrastructure has necessitated the development and implementation of standardized communication protocols to improve interoperability and optimize the operational efficiency of charging systems. This paper critically analyzes several key protocols: IEC 61851, ISO 15118, OCPP, IEC 63110, OCPI, OCHP, OICP, OSCP, OpenADR, and eMIP, with an emphasis on their role in facilitating efficient communication between electric vehicles, charging stations and control systems. IEC 61851 establishes the fundamental requirements for conductive charging, and ISO 15118 supports advanced vehicle-to-grid (V2G) communication, enabling two-way energy flow and increasing grid stability. The Open Charge Point Protocol (OCPP) standardizes communication between charging points and central control systems, promoting system architecture flexibility. Additionally, OCPI and OCHP enhance interoperability by enabling seamless roaming between different boot networks, thereby improving accessibility for users. OSCP provides a smart charging framework enabling real-time load management and energy optimization. OpenADR and eMIP facilitate demand response and data exchange between stakeholders, contributing to a more integrated and efficient EV ecosystem. This review clarifies the interrelationships between these protocols, highlighting their common importance for the development of a sustainable electric vehicle charging infrastructure and their implications for the future development of intelligent transportation systems.

2 Key Protocols Overview

IEC 61851 - Standards for conductive charging and communication requirements.

IEC 61851-1 is a global standard that describes the essential requirements and test methods for electric vehicle (EV) charging systems. Its full title is "IEC 61851-1: Electric vehicle charging systems - Part 1: Essential requirements". This standard is part of a series developed by the International Electrotechnical Commission (IEC) that aims to ensure the safety and compatibility of electric vehicle charging infrastructure.

The standard describes criteria for wireline charging systems, including operational safety and interaction between electric vehicles and charging stations. Additionally, it focuses on the compatibility of components in charging systems. Within the standard, different charging modes are defined, including Mode 1, Mode 2, Mode 3, and Mode 4, each with specific requirements regarding power level and charging safety. In article [1], this standard was used, and an algorithm was developed to achieve scheduled charging of electric vehicles by optimally tracking a target signal. Various scenarios were played out by forming groups of vehicles. There is also a second edition of this protocol [2] which supersedes the first edition published in 2001. It is a technical revision.

ISO 15118 - Vehicle-to-grid (V2G) communication for bidirectional energy flow

ISO 15118, officially called "Road Vehicles - Communication Interface between the vehicle and the network", is a set of standardized rules developed by leading organizations such as the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). At its core, this standard ensures compatibility and interoperability between all-electric vehicles and charging stations, regardless of their manufacturer, brand, or charging technology (for example, AC versus DC charging). In [3], a review was made of this standard, emphasizing the advantages of using this communication protocol. Also presented is the functionality it offers, allowing electric vehicles to feed energy back into the grid without disrupting its stability, with the aim of achieving a two-way flow of energy.

Vehicle-to-grid (V2G) technology is an innovative solution to improve the connection between electric vehicles (EVs) and the electricity grid. It provides a number of benefits, including the ability to integrate distributed energy sources (DER), support grid stability and efficient peak load management, and contribute to reducing the environmental footprint. A study [4] is presented in which a comprehensive overview of V2G systems is made, emphasizing the role of communications and challenges. Environmental implications are discussed, concluding with implications for battery quality, grid integration, power electronics, and electromagnetic interference issues.

OCPP (Open Charge Point Protocol): Standardization of communication between charging stations and management systems.

The ability of software and hardware systems to exchange data is a major factor in the successful development of electric vehicle production. The Open Charge Point Protocol (OCPP) was created and developed by the Open Charge Alliance (OCA), an alliance of European industry organizations. It is designed to provide interoperability in communication processes and smart charging management between electric vehicles and charging stations. OCPP is an open protocol that is used for charging stations to reduce investment costs and provide greater security. This aims to facilitate the provision of network services related to smart charging. The charging infrastructure for electric vehicles includes the following main elements shown in Table 1: an electric vehicle, a charging station, a charging management system (CSMS), and an electricity grid or other sources of electricity. [5] the charging station provides a physical connection to the electric vehicle and provides a certain amount of power for charging. To ensure proper charging and maintenance of the battery, the EVSE (as an element of the charging station) must be connected to the battery management system (BMS) of the electric car. Various technologies, such as Power Line Communication (PLC) or Controller Area Network (CAN), can be used to carry out this communication, the latter being preferred by many vehicle manufacturers in India.

Table 1. Commonly used terms, [5]

Term	Meaning
Charging Station	The Charging Station is the physical system where an EV can be charged. A Charging Station has one or more EVSEs.
Charging Station Management System (CSMS)	Charging Station Management System: manages Charging Stations and has the information for authorizing Users for using its Charging Stations.
Electric Vehicle Supply Equipment (EVSE)	An EVSE is considered as an independently operated and managed part of the Charging Station that can deliver energy to one EV at a time.
CSO	Charging Station Operator
EV	Electric Vehicle
RFID	Radio-Frequency Identification

There have been three major versions of the OCPP protocol since its existence: OCPP 1.5, OCPP 1.6, and OCPP 2.0.

- OCPP 1.2: This version of OCPP is similar to OCPP 1.5 but with a more limited feature set.
- OCPP 1.5

The OCPP 1.5 protocol describes 25 different operations, of which 10 are initiated by the charging station and the remaining 15 by the central control system. Among them are: authorization, boot start and stop, notifications, data transfer, status diagnostics, firmware status notifications, communication status (Heartbeat), meter values, transaction start, transaction notifications, as well as configuration management, diagnostics, and firmware update functions. [6] also included are operations such as reservation, updating a local list, and advanced remote process management features such as starting and stopping transactions.

• OCPP 1.6: Key features and technologies
OCPP 1.6 is one of the most widely used versions of the protocol and uses SOAP (Simple Object Access Protocol) to exchange messages between charging stations and centralized control systems. All charging stations manufactured after the OCPP 1.6 announcement date support communication through this version of the protocol using web sockets. SOAP is a standardized method of communication that ensures reliability in the transmission of messages in the Internet environment. The messages in OCPP 1.6 are formatted using XML (Extensible Markup Language), which allows for easy data structuring.

The use of SOAP and XML offers several advantages, including stability and security of information transmission, which is especially important for the integration of different charging stations and networks [7], but with the development of cybersecurity and new web standards, OCPP 1.6 needs to be updated.

To improve data exchange processes, the OCPP 1.6J protocol has been developed, which is currently established as the most used protocol. It supports JSON (JavaScript Object Notation) format for organizing messages. Version 1.6J introduces specific improvements that mainly relate to the management of more complex operations, and connection security, and provides additional functions for data exchange and information retrieval. For example, OCPP 1.6J supports the charging management function by adapting power depending on the network capacity and specific user requirements and also offers better data protection mechanisms and communication encryption. This makes OCPP 1.6J more suitable for applications requiring higher security and dynamic resource management, such as smart charging and integration with renewable energy sources. Because of this, all modern charging stations support OCPP 1.6J or later version of the protocol.

• OCPP 2.0: Innovations and New Opportunities
OCPP 2.0 is the latest protocol update, which was introduced in April 2018. This version meets the requirements for faster and more flexible communication by using the JSON format of data transmission, as in 1.6J, [8]. OCPP 2.0 also adds a number of new functionalities, including improved charging management, advanced security, support for smart charging, and better integration with the ISO 15118 standard, which allows for direct communication between electric vehicles and charging stations. Other improvements include display management and awareness capabilities, as well as expanded device support and smart charging features.

A major drawback of version 2.0 is the delayed compatibility in the firmware of charging stations. Charging station manufacturers are developing hardware and firmware that offers compatibility with version 1.6J. This is a significant problem that should be solved in the coming years.

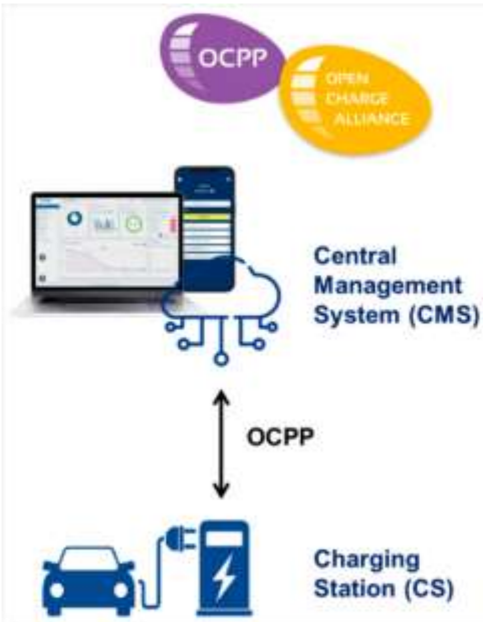

Fig. 1: OCPP is a main communication protocol for data exchange between CMS and CS, [9]

OCPP is a main communication protocol for data exchange between CMS and CS (Figure 1), the OCPP Technology Framework bases its effectiveness on the use of open-source communication protocols that promote shared responsibility for creating high-quality electric vehicle charging infrastructure. The ability to use open protocols provides numerous advantages, such as wider use, easier modification, and a wide variety of solutions, [10]. OCPP interoperability plays an important role in the standardized exchange of data and diagnostic information between a charging station, a station management system, and station owners. This leads to the standardization of management systems, the development of libraries for data processing and synthesis, and the development of solutions for data collection, analysis, and visualization. All these approaches are expected to lead to the optimization of charging processes, distribution of consumption, improvement of maintenance, and more.

Standardization of data exchange is important not only for increasing efficiency but also for the development of new energy services and innovative business models, such as virtual power plants (VPP) and peer-to-peer energy trading.

IEC 63110: Framework for the management of charging infrastructure.

IEC 63110 is a standard created by Joint Working Group JWG11, which is part of IEC Technical Committee TC69. The development process started in November 2017. on the initiative of France, Germany, and Italy. JWG11 brings together the expertise of two main technical committees. IEC 63110 is an international standard aimed at the optimization and coordination of processes related to the charging of electric vehicles and the accompanying infrastructure. [11] this standard lays the foundations for the efficient exchange of data and information between different components in the electric mobility ecosystem, including interaction with energy networks. The standard aims to ensure seamless integration between the participants in the loading process while ensuring a high degree of compatibility and data security.

The main areas covered by the standard include:

1. Energy transfer management – regulation of the charging and discharging process of vehicle batteries, as well as the exchange of information related to the energy requirements of charging stations, network usage, and contractual parameters. These processes also include monitoring of energy consumption measurement data.
2. Charging station management – monitoring and controlling the assets that power electric vehicles. This includes updating software components, configuring boot profiles, and providing support for physical devices.
3. Security and authorization – the authentication and authorization processes of charging sessions, including managing roaming services, collecting metering data, and regulating pricing. An important aspect is the integration with various payment systems and monitoring of energy transactions.
4. Additional services – the inclusion of additional functionalities, such as charging station reservations, which contribute to overall system efficiency and resource optimization within the electric mobility ecosystem.

This approach allows to creation an integrated and secure electric mobility environment, ensuring interoperability between different technologies and platforms.

OCPI (Open Charge Point Interface): Enhancing interoperability and roaming capabilities.

The OCPI (Open Charge Point Interface) protocol was created by the eViolin team, a joint initiative of Dutch operators of charging stations and mobile platforms, in partnership with ElaadNL. The first official version, OCPI 2.0, was published in 2015. The protocol is currently managed by the EVRoaming Foundation, which includes organizations such as Freshmile, ChargePoint, Google Maps, GIREVE, Last Mile Solutions, and NKL. [12] in the context of roaming protocols for electric vehicles, OCPI is distinguished by being the only protocol not managed by an organization also providing roaming services. The latest version, OCPI 2.2.1, was introduced in 2021 and is licensed under the MIT license. This protocol is easily integrable, and about this feature, a new approach to designing intelligent charging systems using OCPI as the deciding factor for the interface between the EMS and the operator is proposed in [13], and the system has been validated and tested.

OCHP (Open Charge Hotspot Protocol): Facilitating cross-network communication.

The initial publicly available EV Roaming Protocol, known as OCHP, was introduced in 2013. by the organizations Smartlab Innovationgesellschaft and ElaadNL, which were respectively established by German and Dutch utility providers. [12] the protocol is used by e-clearing.net, a non-commercial roaming center operated by these same organizations, which later transformed into a private enterprise. The most current version of the protocol, OCHP 1.4, was released in 2016, at the same time the OCHPDirect 0.2 extension was introduced, which enables peer-to-peer (P2P) connectivity. The OCHP protocol is licensed under the MIT license.

OICP (Open Charge Point Protocol): Standards for billing and service access.

The OICP protocol was established in 2013. by Hubject, a consortium of leading German companies including BMW Group, Bosch, Mercedes-Benz, Volkswagen Group, EnBW, Siemens, Innogy, and Enel X. [12] the main purpose of this protocol is to facilitate the roaming process for electric vehicles by using Hubject's centralized roaming hub. The latest version of the protocol, OICP 2.3, was released in 2020. The license under which the protocol is distributed is Creative Commons Attribution-Share Alike 4.0. This is one of the major roaming protocols and in Table 2 you can see the other ones.

Table 2. Major roaming protocols in Europe, [14]

Protocol	Proprietary / independent	Supports roaming hubs	Supports peer to peer connection/decentral
Open Clearing House Protocol (OCHP)	Proprietary (e-Clearing.net)	YES	YES
Open InterCharge Protocol (OICP)	Proprietary (Hubject)	YES	NO
eMobility Inter-Operation Protocol (eMIP)	Proprietary (Gireve)	YES	NO
Open Charge Point Interface Protocol (OCPI)	Independent	YES	YES

OSCP (Open Smart Charging Protocol): Smart charging management and load balancing.

OSCP (Open Smart Charging Protocol) is a protocol used to manage the smart charging of electric vehicles (EVs) and load balancing in the energy grid. Its main goal is to ensure efficient interaction between charging stations and network operators, allowing optimization of the charging process according to the current network load and available energy resources. At the same time, OSCP provides the ability to dynamically regulate charging, taking into account the time slots with lower electricity prices and minimizing the load during peak hours. Through this protocol, significant savings in energy resources are realized and the stability of the electricity network is improved, reducing the need for additional capacities and reducing the load on the infrastructure. OSCP also promotes the development of sustainable and efficient charging solutions for electric vehicles, while providing opportunities for the integration of renewable energy sources into the charging process.

eMIP (electric Mobility Integration Platform): Data exchange and ecosystem integration

The eMIP protocol was created by GIREVE, a French consortium including organizations such as EDF, Renault, CNR, and Caisse des Dépôts. The initial operational version of the protocol, eMIP 0.7.4, was released in 2015. and since then, GIREVE has continued to be the primary roaming hub requiring certification to connect to its platform. Although the protocol has undergone a number of updates to add new features and capabilities, these changes have not necessitated an update to the protocol itself. [12] the periodic releases of description documents and implementation guides, which continue until 2020, have mainly focused on the newly introduced functionalities. Users of eMIP receive a license to use issued by GIREVE.

OpenADR (Open Automated Demand Response): Demand response capabilities and grid integration

OpenADR (Open Automated Demand Response) is an open standard for automated energy demand management, which is used to optimize energy consumption in electricity supply networks. Its main features include: Automated management of energy consumption, allowing energy network participants (such as businesses and consumers) to automatically respond to signals of changing electricity prices or peaks in demand without requiring manual intervention, [15].

The OpenADR protocol can be combined with the OCPP protocol. This combination aims to optimize the charging processes of electric vehicles by managing the load on the power grids. In addition, OpenADR allows the use of electricity from solar panels and other environmentally friendly sources of electricity. Balance management is carried out by electricity providers and system operators, who communicate with end users via the Internet. Consumers can reduce or redirect their energy consumption during periods of high demand, thus achieving grid stability and efficient use of energy resources. These measures would lead to lower energy costs and lower carbon emissions.

3 Interoperability Challenges

- Existence of multiple protocols other than OCPP for communication and management of charging stations;

Many different protocols lead to the need to create complex control systems that must support each protocol. Additionally, upgrading and compatibility for each protocol becomes difficult to track and integrate.

- Lack of standards for integration of payment and booking systems;

Payment and booking systems are mandatory elements to ensure refueling. Their integration into station management systems requires the introduction of standards to ensure security and successful transactions. In addition, these systems must be integrated into user applications and provide convenient and secure use.

- Ensuring security in terms of authorization and authentication;

These processes are the basis for developing custom applications where each user will book, load, and pay. Here, it is often necessary to carefully design the software architecture and provide various authentication methods. With regard to authorization, rights are defined according to the type of user, which is reflected in the management system of charging stations.

- Ensuring security in data transmission and remote control;

With the development of communication protocols, compatibility with the latest and most reliable methods of data encryption and encryption must be ensured. In addition, secure web sockets and other communication channels should be used.

- Improving the processes of charging, load balancing, and use of energy from renewable sources;

It is necessary to monitor and analyze the load on the electricity transmission network. The integration between OCPP and OpenADR needs to be strengthened by developing innovative optimization and planning methods.

Lastly, roaming agreements and billing systems are still all over the place. Without standardization, it's like trying to navigate a maze just to charge your car. And that's exactly what could slow down the adoption of electric vehicles. We need things to work better, faster, and easier for everyone, or it's going to be hard to get to where we want to be.

4 Future Developments and Load Balancing

Addressing these interoperability challenges requires a collaborative approach between stakeholders, including manufacturers, service providers, regulatory bodies, and industry associations. By developing and deploying end-to-end solutions, the EV ecosystem can improve interoperability and ultimately support the transition to a more sustainable transportation future. As in our future developments, we will focus on the implementation of a method and approach for an optimization (control) module, distributing the energy flow in order to avoid network overload. Load balancing or the so-called load balancing, is power balancing EV charging without overloading the electric system in the building.

Static load balance distributes available power between one or more stations for charging of EV. This guy balancing on the load does not report the general consumption of energy in the building, but instead, this balance only relative to the definite level of power.

Dynamic load balance improves common stability in electric building systems through the distribution of power between everyone points for charging. He supports permanent levels of tension and decreases the risk of surges or declines in the power supply. Through continuous monitoring of consumption of energy on everyone's devices, Dynamic load balancing regulates the power sent to the EV. In this way prevents overload and se supports safe balance in the electrical infrastructure of the building.

The key differences between static and dynamic load balance:

- Static balancing on the load distributes power up based on in advanced defined system or algorithm. He did not react to changes in the demand for energy in real-time. This approach works well in environments where the energy one needs is predictable and stable.
- Dynamic balancing on the load continuously monitors and corrects the distribution on the power-up basis on the demand in real-time. This one system is applicable in environments where the consumption of energy can vary unpredictably.

5 Conclusion

Communication protocols are the primary means of accessing and managing charging stations. Development and research in this area lead to the improvement of management methods and systems. The main protocol for retrieving data and commanding charging stations is OCPP. Current web systems and servers as well as all models of charging stations support this communication protocol. The integration of additional protocols and future research on systems issues will hopefully contribute to solving the challenges presented.

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During the preparation of this work the authors used a language editing tool for language improvement. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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