# *Electric Vehicles Charging Network*

# *Towards e-Roaming Protocol Standardization to Achieve Interoperability*

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# Electric Vehicles Charging Network: Towards e-Roaming Protocol Standardization to Achieve Interoperability

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**Sommario**

In Europa, il progresso nell'adozione dei veicoli elettrici (EV) varia notevolmente da paese a paese e da città a città. Comprendere questa variazione è importante per identificare politiche e azioni efficaci per accelerarne ulteriormente l'adozione. I principali fattori che influenzano l'aderenza da parte dei clienti finali al mercato degli EV, oltre ai prezzi di acquisto, sono il driving range, i tempi di ricarica e le strutture di ricarica (Sierzchula, al., 2014). In particolare la mancanza di standardizzazione delle infrastrutture di ricarica ha conseguenze immediate sulle prestazioni delle auto elettriche, poiché interagisce con i temi della durata delle batterie e della disponibilità delle colonnine. A questo proposito viene studiato il processo di standardizzazione nel mercato della ricarica dei veicoli elettrici come processo per impostare comunicazioni di back-end che consentono l'interoperabilità all'interno della rete, utilizzando protocolli di e-Roaming. I protocolli di e-Roaming consentono agli utenti di veicoli elettrici di viaggiare attraverso i paesi e di ricaricare in diverse stazioni mentre accedono al proprio sistema di comunicazione e pagamento.

**Abstract**

The main factors influencing the adoption of electric vehicles are, in addition to price, driving range, charging time and charging structures (Sierzchula, at al., 2014). In particular the lack of standardization in the recharging infrastructure has immediate consequences on the performance of electric cars, since it interacts with the issues of duration of batteries and location availability of charging stations. We study the standardization process in the EV charging market as a process for setting back-end communications that allow interoperability within the network, by using e-Roaming protocols. E-Roaming protocols allow users of EV to travel across countries and to recharge in different stations while accessing to their own communication and payment system. We build up an original dataset on roaming protocols, apply Social Network Analysis measures and discuss the findings in the light of economic theories of network externality, platforms and standardization.

# 1 Introduction

The research objective of the thesis is to describe the role of e-Roaming protocols within the European EV charging network and to investigate the standardization process to achieve interoperability.

# 2 Literature Review

The lack of charging infrastructure is a serious barrier to adoption in the electric vehicle market. The low territorial density of charging stations creates what is labelled "range anxiety". As a result, the development of a robust charging infrastructure network is currently considered one of the keys for the large-scale transition to electromobility. While in Europe through de-jure standardization, the compliant hardware infrastructure (plug-in) was established, so that users can charge various car models at different stations, there is lack of interoperability in the communication between the user and the charging station, and hence between the payment and the billing/receipt phases of the consumption process. This is particularly problematic for cross-country mobility.

## 2.2 Design of the EV Charging Network and Relationships Between Network Actors

Within the charging market, we identify separate networks, that include EMSPs (Electro Mobility Service Provider, that is, the legal entity whom the customer has a contract), IT service developers (software companies providing back-end application, services or cloud platforms), CPOs (Charging Point Operator, or companies responsible for management, maintenance and operation of the charging stations) and EV (electric vehicle) users (Fanti et al., 2017). EMSPs and IT providers create platforms that connect CPOs and customers[1]. In order to permit the EV users to use a electricity network without being a registered customer it is necessary that an agreement between the two networks is in place, or that a general unified agreement among all network actors is established. Alternatively, ad hoc payments, if available, are also an option. The agreement allowing this communication is labelled e-Roaming and it is the main object of this thesis. The process for converging in a fully agreement is complex and often dominated by strong positions. Powerful players compete with each other and are not willing to cooperate (Van der Kam & Bekkers, 2020b). This creates room for public intervention.

## 2.1 Standardization Theory and Multisided Platform Economy

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[1] This is the case in which each market actor covers just one role (the business models will be discussed in chapter 4)

The standardization can be classified as voluntary (consensus-based) or market driven. Standardization is one important way to achieve compatibility and interoperability in networks (Belleflamme, 2002). Given these positive outcomes of standardization, a large literature has examined the way in which social actors coordinate among themselves and achieve an agreement (Hanseth, Monteiro & Halting 1996). Standardization studies describe the interactions between actors that may or may not share joint interests. When actors follow divergent use scenarios, the emergence of a dominant design is associated to permanent competitive tensions (Fransman, 1999). The complexity of the decision-making process and the impact of standards design on firm profitability can make the standardization process intensely competitive. However, the strategic meaning of coordination standards, in particular compatibility standards, does not ensue from the fact of promulgation *per se.* Rather, they achieve a quasi-mandatory status as a consequence of coordination externalities and more specifically network externalities (Shapiro & Varian, 1999).

Platforms can be considered double-sided markets, as markets mediate transactions across different customer groups. In platforms the network effects fuel platform competition (Gawer, 2014). While the definition of platform refers to isolated, individual networks, in the case of EV charging infrastructure we will see how the need to coordinate several platforms is addressed, creating a more complex governance issue for interoperability.

## 2.3 Roaming

For the EV users, besides, to join another network without joining it directly means the necessity of the communication[2] between the two networks or alternatively the existence of a large, unified network. E-Roaming allows this communication[3]. Roaming hubs provide immediate access to a large network by using a central clearing house. In Europe there are some interoperability protocols that allow e-Roaming connections in the electromobility. The main competitors are: the Open InterCharge Protocol (OICP); the Open Clearing House Protocol (OCHP); the Open Charge Point Interface (OCPI) and the eMobility Inter-Operation

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[2] Roaming agreements and transaction clearing between charging network operators can be done on a bilateral basis. This connection is defined a direct roaming (peer-to-peer) according to Van der Kam and Bekkers (2020a) analysis. Peer-to-peer software are solutions for the management and for the billing, agreements are flexible and customisable, since the operators can discuss over the technical and commercial aspects. However negotiate many connections can result expensive, especially require significant technical costs, and absorb time (Van der Kam and Bekkers, 2020).

[3] Indirect roaming (e-Roaming) can be provided by roaming hubs. Roaming hubs allows immediate access to all the other parties connected to that platform, resulting in a harmonized framework of commercial roaming agreements. The disadvantage implications include lower span of control, since roaming hubs decide what protocols to use and dictate the business rules (Van der Kam and Bekkers, 2020). The use of a roaming hub does not exclude eventually peer-to-peer agreements.

Protocol (eMIP).

Table 1: Governance aspects of e-Roaming Protocols

|  | OCHP | OICP | eMIP | OCPI |
|---|---|---|---|---|
| Managed by | e-clearing.net | Hubject | GIREVE | NKL |
| Firms and / or Organisations interested | Smartlab Innovationsgesellschaft GmbH and ElaadNL | BMW Group, Daimler, Bosch, EnBW, EnelX, Siemens, Volkswagen, and Innogy | EDF, Renault, CNR, Caisse des Dépôts | eViolin and ElaadNL |
| Managing organisations operate at the same time an associated roaming hub | Yes but hub role is non-exclusive | Yes | Yes | No |

Roaming standardization has been largely studied in the Internet and Telecom sectors. However transactions in the telecommunications market are much more frequent and have lower economic value, so roaming in telecommunications makes much more sense than ad hoc payments, while this is not taken for granted in the charging sector (Van der Kam and Bekkers, 2020). Moreover a feature that differentiates the world of telecommunications from that of the Internet one is the low level of hierarchy in the second one (Ferwerda, et al., 2018). This is reflected in the fact that the individual contributions made to the Internet world are due to "individuals" rather than to companies or organizations and for this reason the most elaborate activities are carried out by the end user.  For this reasons the two previous cases are not fully applicable to the electric charging sector.

## 3 Methodology

This research follows deductive approach, in which a hypothesis is deduced based on the existing theory. I adopt a qualitative approach given the sheer complexity of the phenomena under investigation. A quantitative analysis of the network structure of e-Roaming arrangements will serve as qualification and validation of the qualitative approach. Multiple data sources have been triangulated, including scientific papers, protocols' and platforms' web pages, online magazines, webinars and direct interviews, collecting more than 100 sources altogether. However, some limitations remain due to the lack of data[4].

## 4 Findings

This chapter provides information on the current European EV charging industry and discusses the business models adopted within the networks and the standardization

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[4] See the thesis for clarifications.

initiatives in place. It develops a collection of country case studies. The scenarios of future network organization are extensively discussed on the basis of the comparative analysis of country case studies.

**4.1 Current European EV Charging infrastructure state**

The European charging market shows high fragmentation especially along the value chain and business models are undergoing change (D. Little, 2020). Although official data is not available, it is reasonable to assume that the market is not profitable, for the time being. But because the market has a large potential and is expected to become profitable in the near future, companies have to take a position now.

The EMSP, in addition to having contact with the customer, provides the service (through a mobile app or RFID card or other solutions) and invoices the consumer, defining the final price. The CPOs run, maintain and own the charging stations and can base their primary business on the charging itself or add it as an additional service to attract customers to their primary business. IT service providers, instead, develop software that allows direct or indirect connections between EMSPs and CPOs, providing back-end applications. However many EMSPs and CPOs already have their own IT teams. Some CPOs already provide IT and administrative services for other CPOs and EMSPs. The responsibilities and decision-making rights of each role are not easy to define and this leads to a lack of transparency even for the end users. It must be reminded that the same actor (firm) may play several roles in the network. In the EV charging ecosystem business models and development scenarios are constantly reshaped, resulting in a critical assignment of who can capture new value. Finally, interoperability platform are considered as mature business models (Capgemini, 2018), adopting sizeable fee, but they are still insufficient to establish interoperability on a larger scale.

**4.2 Scenarios**

In the Status Quo the European market is made up of individual networks that can interact through one or more roaming hub. The result is a fragmented market where EV users can access a small circle of charging stations not equipped with hoc payments. However if the use of a protocol becomes widespread then the protocol becomes dominant, resulting in a switching to that protocol by all the market actors, to reap the benefits of network externalities and eliminate the costs of adopting "loosing" protocols. This represents "*a protocol winning the battle of standards*" scenario. Interoperability is achieved and, without cooperation, implementations and updating will be faster. The "*harmonization of existing*

*protocols*" scenario, in opposition, represents an international cooperation between all protocol developers, resulting in the creation of a harmonized protocol that includes all the existing functionalities. Another option to make the network open is the use of gateways that connect different protocols. In this scenario, interoperability is achieved by connecting protocols via gateways, with the highest possible level of functionality. This scenario already exists partially thanks to the cooperation of some hubs. It has the benefit of preventing the rise of a monopoly and is attractive if a standard has not established itself or been established. Some European efforts to reach this agreements emerged, for example GIREVE and Hubject with the Pan-European initiative, tried to connect e-Roaming platforms for customer-friendly charging of electric vehicles across national borders, but Bayings (2021) from the evRoaming4EU Foundation, in a personal communication, claimed that this initiative never became reality. Furthermore the IEC has begun to develop an international protocol (IEC 63119) that could establish itself as a standard, as it is developing by a large global and formal standards-setting organization (SSO). The protocol is still under development and could be ready in two years. Finally, the latter scenario is represented by no roaming but ad hoc local payment instead. In this scenario, both the role of e-Roaming hubs and the one of EMSPs disappear. This is because EV users are guaranteed direct access through ad hoc payment.

### 4.3 Country cases studies

In the thesis I develop five extended and detailed country case studies, summarized here. In terms of EV market share, The Netherlands and Norway can be considered at the forefront of the EV revolution. Following, UK, France and Germany are also leading the transition to the electromobility. Although they all have good intentions their charging infrastructure markets have been built differently and seem to go in different directions. In this regard understanding these differences is important in identifying the network direction. The Netherlands and Portugal have promoted bottom-up interoperability, albeit with different agreements. The Dutch EV market was pushed (2010) under the direction of the central government, in collaboration with many parties, and it resulted in a 100% interoperable with the larger EV charging infrastructure. In opposition the Portuguese Government promoted a sort of monopoly and in 2015 the Government was forced to take a step back and acknowledge the inefficiency of the monopolistic market. Germany (together with France) represent a hybrid model, which has not yet reached national full interoperability but is still moving in that direction supported by recent public subsidies. In fact (since 21017 both

Germany and France), to compete for public grants the operators must ensure e-Roaming[5] for all customers. In Norway and the UK the networks are mostly closed but a top-down rise of interoperability in the market is not excluded. Norway is the European front-runner in EV sales, and it showed up how his market worked even without the support of an interoperable scenario. In the UK the desire for an open network didn't emerge yet, among the most parties who prefer to adopt niche strategies.

Hence, the following research questions are set:

1. "How do costs and benefits contribute to accelerate the standardization?"
2. "When and where are strategies market driven or government supported?"
3. "How do the differences across countries contribute to set up a possible European scenario?"
4. "Is there a leadership among the main e-Roaming protocols?"

**5 Analysis**

**5.1 Market and Cost Considerations**

Bilateral agreements are often less expensive for small operators who do not have the financial resources to invest in e-Roaming agreements and might be reluctant due to the uncertainty of the benefits deriving from those investments. On the other hand, however, large operators may have a swollen portfolio that makes peer-to-peer agreements adequate for profitability (Van der Kam and Bekkers, 2020b). This imbalance, added to the reliability of the EV market, may delay the achievement of an interoperable network and therefore of standardization. In this perspective, legislative authorities play a fundamental role. In recent years subsidies to operators have been made conditional on the connection to e-Roaming platforms, for example in Germany. However, interoperability is supported on a national level, while international agreements receive more stimuli from the market dynamics. Finally the public subsidies, that aim to cover the costs, are a good incentive to participate in the market and limit the verticalization of the market, but questions remains on how efficient are regulations to avoid the empowerment of few operators, which might be capable of controlling the market without promoting any e-Roaming adoption.

**5.2 Qualitative Analysis of the EV Charging Network Scenarios**

The pure mode of standard selection can be cooperation based or competition base. A process that is based on a mix between the two is regarded as a hybrid mode (Oshiri, 2006).

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[5] In France the GIREVE platform is mandatory.

A standard can emerge as a *"compromise between mutually competing networks"* (Oshiri, 2006:268). Harmonization of existent protocols represent a compromise, while competition cover the battle for standard scenario and cooperation represent the global standard IEC 63199 domain. Harmonization process is that a merger process that probably requires the involvement of a coordinating body, while the market tends to make more pragmatic choices than governments. The gateway scenario achieves interoperability, but no protocol standardization emerges.

Table 2: Characteristics of the scenarios

| | Status Quo (Fragmentation) | Harmonisation of existing protocols | Standards Battle with winning protocol | Gateway that connect different protocols | IEC 63199 standard become dominant | No roaming but ad hoc payment |
|---|---|---|---|---|---|---|
| **e-Roaming agreements** | v | v | v | v | v | x |
| **Peer-to-peer agreements** | v | v | v | v | v | x |
| **Compete on protocol functionalities** | v | x | (Need for keep the dominant position) | v | x | x |
| **Compete on services/BM** | v | v | x | v | v | x |
| **Important role of legislators** | x | v | x | uncertain | v | x |
| **Strategies market driven** | v | v | v | v | x | v |
| **High implementation costs** | v | x | x | v | x | x |
| **High adopting costs for operators** | x | uncertain | uncertain | x | uncertain | x |
| **Single standard** | x | v | v | x | v | x |
| **High level functionalities** | v | x | uncertain | v | uncertain | x |
| **Monopoly** | x | x | might be | x | x | x |

Table 3: Protocols scenarios and Country cases studies.

| | Status Quo (fragmentation) | Harmonisation of existing protocols | Standards Battle with winning protocol | Gateway that connect different protocols | IEC 63199 standard become dominant | No roaming but ad hoc payment |
|---|---|---|---|---|---|---|
| **The Netherlands** | | Single standard is advantageous | Full interoperability | | | |
| **Portugal** | | Lower implementation costs | | Possibility to adapt their national MOBI.E platform | | |
| **Germany** | Competition between protocols | | Hubject is a German platform | Reduce risk for monopoly, easier to support different context | | |
| **Norway** | Geographically suitable | | | | | No roaming fee and costs |
| **United Kingdom** | Market driven, competition, niche strategies | | | | | Closer to the current ICE customers experience |

## 5.3 Network analysis

A network can be conceptualized as a system of edges and nodes that are interconnected; such nodes can be either individual or collective. Roaming hubs, assumed as platforms,

aggregate firms covering the same role (EMSP or CPO) in the market, giving rise to cooperation between competitors. A roaming hub does not operate and monitor charging stations but it acts as a marketplace for CPOs and EMSPs. Dominant platforms may play a role in the formation of standards where de facto industry standards settle down once the platform has achieved a critical mass of network users (Bonardi & Durand, 2003). The graph visualization, as node-link diagrams, is ideal to represent a network of relationships. The importance of nodes is crucial to graph theory and can be defined calculating its centrality. Nodes with high centrality are important controllers of power or information. I built three datasets using data available on the web. The first dataset was built to represent the visualization of the graph (Figure 30 in the thesis, not reported here for reasons of space limitation). It is a graph representation of which platforms / OCPI protocol (as an independent protocol[6]) reach respectively the different European countries. The second network visualization (Figure 31 in the thesis) is based on a dataset made by collecting data from the platforms web pages in order to capture all the partnerships[7] among the e-Roaming hubs and the operators. Based on the topology of the network I calculate the eigenvector[8] centrality. In sequence, the highest influence belongs in order to Hubject, e.clearing.net, OCPI and GIREVE. Two considerations are relevant in this regard: Hubject shows his strong position as first-mover and even if GIREVE links more operators, the impact of OCPI is larger due to the important players that it links. In addition, because among the e-Roaming customers, some companies are centrally[9] positioned in the charging market, we expect their decisions to influence the success of the platforms. The third graph (Figure 34 in the thesis) represents the physical charging networks all over the Europe, according to Open Charge Map[10] data. The network visualization shows how the countries' clusters including Germany, UK, Spain, France, Italy and Switzerland have a large number of networks, but of local size. Netherlands and Norway, the two front-runners in the electric race, are placed centrally. Their placement demonstrates that the operators of their local networks are internationalized companies competing not only in their countries but also all over the European market. The analytic interpretation, instead, gives significant results through the eigenvector centrality. It is interesting to observe (Figure 33 in the thesis) the centrality role

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[6] Refer to Chapter 2.

[7] Being a partner does not necessarily mean having commercial agreements with all the partner operators of the platform.

[8] It is the measure of the influence that a node has on a network.

[9] Higher eigenvector centrality

[10] A global public register of the networks of charging stations for electric vehicles. https://openchargemap.org/site/country

of Tesla, Lidl and Essent (they scored the higher values of centrality but they actually don't adopt e-Roaming agreements). While the incumbent automakers are still focused prevalently on making the most competitive electric cars, Tesla has been thinking of solving consumers' core driving needs, like charging the car. However the Tesla business case, in the context of this thesis, is in the spotlight since Tesla does not engage in opening its network, but rather adopts a non-interoperable business model. Lidl, who strongly competes in its industry, increases the added value with complementary services and free access (or cheap offering), but it is not clear whether it can play a dominant role in the network. Essent is a pure Dutch CPO; not showing up in previous graphs, it shows a business model entirely based on peer-to-peer connections on large scale.

## 5.4 Charging Network Strategies

The relations within the market can be macro-stratified into three levels. There are the activities of individuals, in which companies such as CPOs, EMSPs and in particular those who cover both roles, adopt B2C strategies. Secondly there are the inter relationships between several companies that satisfy the B2B2C market and finally there are the e-Roaming platforms as pure B2B industry. What happens downstream has an impact on the e-Roaming strategy evolution. Expectations on the technology are uncertain and, as mentioned several times, there are conflicting opinions on the clear usefulness of the technology itself and its purpose in the charging market. In particular it is possible that large players, that already made agreements with all the roaming hubs, may consolidate their strong position, if the European scenario evolves in a market without an emerging protocol and small operators disappear. These operators may have the financial resources to compete through peer-to-peer connections. In addition it was seen that some commercial limitations of e-Roaming agreements bring to explore strategic direct agreements among firms to provide higher transparency and lower price to the EV users. However, so far, e-Roaming platforms strategies are growing and increasing. Hubject is getting an advantageous installed base of customers in the East Europe, on the other side the independent OCPI protocol is enjoying success among rivals, with its adoption for example in the UK REA platform or in the Charge Up alliance. E-clearing.net, instead, promoted a new standardized contract model, to attract customers in joying his platform. GIREVE is the only one that seems to remain limited to his national adoption.

## 6 Conclusions

Firms in the charging industry have adopted platform business models to mediate

transactions between EV users and CPs owners, and it resulted in a fragmented market with several networks competing in Europe. In order to address the strategic aspect of interoperability reachable by standardization process of e-Roaming protocols, technological and commercial factors strongly interact. Our conclusions are as follows:

(a) Interoperability is not always a dominant choice. In particular, country-by-country differences emerged. (b) Because climate change has put a lot of public pressure it is expected that the role of governmental authorities could be fundamental in this regard. However market are showing more pragmatic and dynamic choices than governments. (c) In this regard a battle for standard seems to be the most likely scenario. However the unwillingness of operators (CPOs/EMSPs) to switch from one protocol to another or even more take part within a platform, could delay the evolution of this scenario. (d) Analysing the strategic ambitions of players (CPOs/EMSPs) that affect roaming decisions, it emerged that the user base and the consequent network externalities do not yet find application in EV charging business models. Maintaining one's own proprietary network is one of the predatory strategies adopted. (e) However the research for a unified market guaranteed by interoperability may inspire firms to explore open-mindedly synergies and become more competitive not only in the electric sector but all over the automotive industry, since e-mobility industry attempt to disrupt the fossil-dependent transportation industry, accelerating the standardization process. (f) In opposition technological evolution on charging time may change the problem solving approach and result in a more ICE-like experience for costumers, which can upset the business models studied so far and make e-Roaming meaningless.

## 6.1 Theoretical Contributions and Managerial Implications

The thesis confirms the existence of market roles identified in Fanti's (2017) research and contributes to support the Oshiri (2006) theory, which argues the existence of a hybrid standardization model between cooperation and competition. The Van der Kam and Bekkers (2020b) research on scenario was confirmed, implemented and then crossed with country-by-country cases studios. Secondly the thesis extends the platforms and networks studies to this particular ecosystem, where the EV infrastructure has bound to physical locations. Finally the large overview on the European market opens up horizons to the companies willing to take advantage on a competitive and extremely rapid evolving market and made implications for policy makers.