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Developing roaming protocols for EV charging: Insights from the field

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Abstract

As electric vehicles (EVs) become more mainstream, roaming will become an increasingly important topic; more and more EV drivers want to connect to available charging networks. Roaming is enabled via communication protocols, which also allow for services such as information on availability and tariffs of charge points. Currently, there are several roaming protocols in use within Europe. With multiple roaming protocols gateway technologies are necessary to achieve full interoperability of charge points, which has disadvantages such as extra costs and limited functionality. Whether multiple protocols will be continued to used or one protocol becomes dominant in the future does not only depend on technical performance of the protocols, but also on attitudes of stakeholders towards them. To investigate these attitudes, we have interviewed roaming experts across Europe. Our results address current issues in roaming and point to trade-offs in how to proceed in achieving full interoperability for charging infrastructure.

Keywords: Electric vehicles; charging infrastructure; roaming; protocols; interoperability; harmonization

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Nomenclature

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>CDR</td>
<td>Charging Data Record</td>
</tr>
<tr>
<td>CPO</td>
<td>Charge Point Operator</td>
</tr>
<tr>
<td>eMIP</td>
<td>eMobility Inter-Operation Protocol</td>
</tr>
<tr>
<td>EV</td>
<td>Electric Vehicle</td>
</tr>
<tr>
<td>OCHP</td>
<td>Open Clearing House Protocol</td>
</tr>
<tr>
<td>OCPI</td>
<td>Open Charge Point Interface Protocol</td>
</tr>
<tr>
<td>OICP</td>
<td>Open InterCharge Protocol</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>MSP</td>
<td>Mobility Service Provider</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio-Frequency Identification</td>
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<td>SSO</td>
<td>Standard Setting Organization</td>
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1. Introduction

As the electric vehicle (EV) market is maturing, interoperability of public charge points is becoming increasingly important, as it will allow EV drivers to charge anywhere, including cross-border. The lack of interoperability is seen as one of the main barriers to large scale EV adoption (Adam, 2016). Currently, the EU has implemented regulation on the standardization of connecting plugs and mandatory ad hoc payments based on credit cards, cash, or apps (European Commision, 2014). Next to ad hoc payments, roaming protocols can enable access to different charging networks for EV drivers. These protocols facilitate information exchange between back offices of mobility service providers (MSPs) and charge point operators (CPOs). Furthermore, in a roaming system MSPs and CPOs set up contracts for network access. Roaming protocols add further value because they can be used to provide additional services, such as information on tariffs, availability and location.

Currently, there are several roaming protocols in use in the European Union (EU), see Table 1 and ElaadNL (2017). The roaming protocols differ in location where they are used, ownership and organization structure. Furthermore, there are several roaming protocols designed for specific countries or companies, such as Portugal and Plugsurfing. This fragmented situation with many roaming protocols has arisen because they were developed by hubs and organizations serving different countries, companies and interests. The situation is further complicated by the fact that e-mobility is relatively new and business models and market roles are still developing (Madina et al., 2016, Fanti et al., 2017), meaning that it is not yet clear which parties should be connected and what information should be exchanged. Fragmentation also arose for the types of plugs used for EV charging (Bakker et al., 2015), until the EU forced a decision on which plug would become the standard (Wiegmann et al, 2013). The co-existence of multiple protocols stands in contrast to other sectors with a need for roaming, such as telecommunications and the Internet, where dominant standards for roaming have emerged (Ferwerda et al., 2018, GSMA, 2012, Spruytte et al. 2017, DeNardis, 2009).

Table 1. Major roaming protocols in Europe, source: Ferwerda et al. (2018). Independent means not attached to a roaming hub

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Proprietary / independent</th>
<th>Supports roaming hubs</th>
<th>Supports peer to peer connection/decentral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Clearing House Protocol (OCHP)</td>
<td>Proprietary</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Open InterCharge Protocol (OICP)</td>
<td>Proprietary</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>eMobility Inter-Operation Protocol (eMIP)</td>
<td>Proprietary</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Open Charge Point Interface Protocol (OCPI)</td>
<td>Independent</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Ensuring interoperability between charge points via roaming requires that either all relevant stakeholders use the same roaming protocol, or that they use gateway technologies that allow translation and interconnection between systems to the best degree possible. While gateway technologies have some benefits, such as decreasing the chance of monopolies to arise (Blind, 2009), developing and maintaining them may come with extra costs and limited functionality (David and Greenstein, 1990).
Our research objective is to offer insights on how to achieve interoperability that will allow for a Europe-wide infrastructure, for which not only technical operability, but also adoption of a protocol is important. We investigate whether this is feasible (and best done) via harmonization of the different existing protocols into an independent internationally accepted protocol. Furthermore, we explore other options to achieve interoperability, such as a protocol becoming dominant through widespread market adoption or using gateway technologies. Whether parties will adopt a protocol does not only rely on its technical performance, but also on the stakeholder support for and attitude towards the protocol. We have conducted interviews with a wide variety of stakeholders from the EV field, which allowed us to get perspective on the attitudes of stakeholders towards protocols, interoperability, and harmonization. This paper presents preliminary results from our research project. It offers insight on the current state of protocol development, the potential future of the EV market, and how to achieve interoperability.

2. Methodology

We have conducted 32 semi-structured interviews with 35 roaming experts (three double interviews). We approached potential interviewees through the network of the project evRoaming4EU in which this research is carried out (website: www.evroaming4.eu), by asking interviewees for to point us to new potential interviewees, and through visiting the electric vehicle conference EVS32 in Lyon, 19-22 May 2019. Figure 1 presents a representation of market roles and their relation in the EV ecosystem that we use in this project, which we have identified the market roles based on scientific and gray literature on EV charging. We do not claim our scheme to be a definitive one on the EV ecosystem, there are other valid ways of representation. Furthermore, the EV field is still relatively new and developing, and new roles may emerge in the future.

Our interviews were semi-structured, and we sent a summary of the interviews back for to the interviewees for them to check for potential mistakes in interpretation. We investigated the strengths and weaknesses of the current protocols and explored views about the future of EV charging and the role of roaming therein. Firstly, we asked about the current state of the development of roaming protocols. Secondly, we asked how they thought the EV charging field would develop. Thirdly, we investigate whether stakeholders want to move towards a single harmonized protocol or multiple interoperable protocols and what route towards either one of these solutions is preferred and/or feasible.

This paper presents preliminary results, as our research project is ongoing while writing this paper. We have spoken to stakeholders from the Netherlands (13), Germany (11), France (3), Austria (2), Portugal (2), Sweden (2), Belgium (1), and Spain (1). Our interviewees perform the following market roles (often more than one): Regulators/government, standards setting organization, roaming hub, energy supplier, charge point operator, mobility service provider, end user/intermediate user, IT system developer, charging infrastructure provider, and information and app provider. Furthermore, we interviewed five people who work on roaming but are not captured in our scheme: two researchers, one consultant, two representatives from sector interest organizations.

![Fig. 1 Market roles and connections in the EV ecosystem. Note that we did not draw connections between the regulations and governance level to other stakeholders, since these stakeholders are involved in the whole value chain](image)
3. Results

This section discusses the preliminary results from our interview round. Here, we discuss answers on questions related to protocol development, the future of EV charging infrastructure and moving towards interoperability. We have written this section in such a way that the results are not traceable to a specific party. On many topics, the interviewees held either the similar or complementary views. Where there was disagreement we explicitly point this out.

3.1. Protocol development: current state and needs

The first theme of our interviews is protocol development. We discussed which protocols are used, the differences between the protocols, the challenges in protocol development, and the role of regulation in roaming protocol development.

3.1.1. Protocol use

Most of our interviewees have implemented multiple roaming protocols or are connected to multiple roaming hubs, because in this way they can ensure access to a large network for their customers. Some roaming hubs have also incorporated more than one protocol. For example, Gireve and e-clearing.net have implemented the OCPI protocol. In Portugal, which have their own national roaming protocol, OCPI will be implemented for cross-border roaming.

3.1.2. Differences between protocols

The general view that arose from our interviews is that on a high level the roaming protocols are very similar, as they mostly overlap in their goals, supporting functionalities offered, and maturity. Differences in the protocols are relevant on a technical level, for instance in the interpretation of Charging Data Records (CDRs), which forms the basis of the invoice. In contrast to the other protocols, OICP does not support CDR exchange. OCPI is a modular protocol that allows for flexibility in its implementation. This flexibility has advantages and disadvantages. Several interviewees like that they can make custom connections, but this also requires more effort than connecting via a roaming hub, which has more strict demands on how parties implement the protocol. Especially Hubject is considered strict in this matter. The more standardized connection offered by roaming hubs is seen as an easy solution to connect to many parties at once. Furthermore, not all protocols offer real-time data on availability and the charging session and differ in their authorization method.

The most important differences can be found in the governance of the protocols. OCHP, eMIP, and OICP are managed by the roaming hub operators of e-clearing.net (operated by Smartlab and Elaad), Gireve, and Hubject, respectively. The roaming hubs have different types of stakeholders, which matter in protocol development. For example, several stakeholders of Hubject are original equipment manufacturers (OEMs), and they have put a lot of effort in incorporating identification by car (ISO 15118) in OICP. The stakeholders of e-clearing.net are German and Dutch utilities, who have focused more than the other protocols on designing a good interface for grid operators. OCPI is managed by a knowledge platform, and protocol users are encouraged to be involved in its development by proposing new functionalities. All roaming protocol developers organize user involvement, e.g. through workshops, but OCPI is perceived as being the most open to contributions from the community. A management board for OCPI was established in 2018, which in its guiding principles has explicitly stated to continue user involvement.

The protocols also differ in the type of connections they enable. OCHP and OCPI enable peer-2-peer connections, while the other protocols are connected to specific hubs. eMIP in theory also allows for peer-2-peer connections, but it is not used that way.

3.1.3. Progress and challenges in protocol development

All interviewees were satisfied with the roaming protocols they used. The challenges for parties who use multiple roaming protocols are related to the effort that goes into implementing and maintaining the protocols that differ
on a technical level. Several interviewees stated that protocol development needs to follow market developments, not the other way around, meaning that protocol developers should address issues arising from the market and not build modules or functionalities there is no demand for.

One interviewee stated that the biggest challenges in further protocol development can be classified as (1) new and broadened functionalities (e.g. reservation, smart charging), (2) support for new players and market roles (e.g. research institutes), (3) regional challenges in worldwide application (e.g. national legislation in the USA or Japan). Other issues that were often named were security and privacy. One interviewee pointed out that most of the security issues can be solved with mandatory signature fields in protocols, which is currently not the case. Signature fields contain private keys for specific charge points and user IDs. Signatures can ensure that you know where the data is coming from and has not been emulated. Furthermore, signatures can prevent ID-numbers that belong to multiple cards in the system, which is really needed with increasing numbers of EVs. Another interviewee suggested that there should be a central database of IDs for EVs and charge points to avoid duplicate ID-numbers in Europe. One of the reasons mandatory signature fields have not been included so far is that different stakeholders have different concerns about security in the protocols and ID cards. For instance, Chinese parties active in the standardization working groups tend to focus on detecting fraud after the fact, instead of preventing fraud. Furthermore, not every supplier uses the most recent version of the protocol that includes a signature field. A final point that was made is that updating is challenging for protocols because backwards compatibility is of main importance, because many parties have already implemented protocols with which updates should be compatible.

There were also challenges named that did not relate to the roaming protocols themselves but to how the market is developing around roaming. One example is that currently there is a variety in definitions needed to enable roaming (e.g. what exactly is a charge point). Furthermore, roaming contracts are very diverse now, which makes roaming complicated. This is where Hubject’s business model really adds value, given that they work with standard contracts. Another threat in how the market is developing is that MSPs may charge different tariffs to their own costumers than to roaming costumers. This may create the situation that EV drivers still need to have multiple charging passes to be able to charge at lower costs, undoing the progress that has been made in trying to reduce the needed charging passes by setting up roaming systems. Also, some parties do not connect their networks. In the Nordic countries for instance, the charging network is not fully interoperable yet. While the major CPOs (Bee Charging Solutions, Fortum, E.ON, and Vattenfall) do see benefit in making there system interoperable, they disagree on whether they should do so via a hub or with peer-2-peer connections. Even if they are connected, not all parties want to share all their data. For example, OEMs currently do not share data on the state-of-charge of their EV batteries.

3.1.4. Role of regulation

There are several ways in which regulation has played a role in roaming development. The German, French, and Portuguese governments require (partly) publicly funded charge points to connect to a roaming platform. It is uncertain whether this will remain this way, as some parties consider this discriminatory and are lobbying for different regulation. Additionally, there are differences between countries on whether EV charging is classified as a service or as an exchange of goods, which has implications for taxation. This makes international roaming complicated. There are efforts to harmonize this across EU countries, but it is a tricky topic as taxation is a national issue not a European one. Another example of unclear regulation is whether CDRs count as an invoice recognized by tax authorities, which is relevant for the development of protocols. German calibration law (Eichrecht) is also relevant for roaming protocol development. Once issues surrounding how to follow such regulations has been incorporated the protocols, these have the potential to support stakeholders navigating national regulations.

So far, EU legislation has not played an important role in roaming protocol development in most countries. There is EU-wide regulation that charge points should always be accessible with ad hoc payments (i.e. without entering a contract with supplier or operator) (European Commission, 2014), but parties can decide for themselves how they enable this. Now that the market is maturing governments may want to play a bigger role in the future. The creation of the National Access Point register is an example of this.
3.2. Future of public EV charging infrastructure

We discussed several aspects regarding the future of EV charging infrastructure. Firstly, we asked the interviewees to name important trends in the development of EV charging infrastructure. These trends could have an impact on protocol design and require new functionalities to be added. Then, we discussed what and how many stakeholders would be involved in the future of EV charging. This has implications for the number of parties that roaming protocols have to connect.

3.2.1. Important trends

The interviewees named a variety of trends in the development of public EV charging infrastructure. Here, we list and shortly discuss the trends that came up.

- **Fast charging.** Fast charging will probably become increasingly popular mostly along highways or at special locations in urban areas. Furthermore, the charging power of these charge points might increase to 150 kW or even 350 kW. This may have an impact on where EV drivers charge and thus for roaming. The degree to which fast chargers will become dominant in public charging infrastructure is one of the most debated topics in the field. Proponents of fast DC charging reason that it makes the act charging an EV more similar to fueling an internal combustion engine vehicle, which is what consumers would want. Opponents say that AC charging infrastructure is much easier to incorporate in the existing electricity grid, and that widespread AC chargers allow for opportunity charging (at work, shopping centers, etc.) that can fulfill EV drivers’ needs.

- **Creating a seamless user experience.** When EVs become more mainstream, EV drivers will increasingly demand ease of use. This means roaming functionality, in car authentication (e.g. with the standard ISO 15118), and information on the availability, capacity of charge points, but also services surrounding charge points such as information on close by restaurants, entertainment available with the charge point. Companies will offer more full service packages, for instance combining buying a charge point with an energy contract.

- **Higher quality of charge points.** Today, the quality of many charge points is not good enough, there are bugs and they are not always working. Charge points are often publicly financed for low costs, and that really makes a difference in the quality. If charge points get replaced, parties will often go for a higher quality, because it saves maintenance costs.

- **Diverse mix in charging infrastructure.** EVs will be used more diversely and there will be a more diverse availability of types of charging infrastructure, also potentially inductive (wireless) charging.

- **Changes in charging behavior.** Several factors will lead to changes in charging behavior. One factor is greater battery range, which may reduce the relative number of roaming sessions. Another factor is changes in mobility use, such as car sharing and autonomous driving. Furthermore, if the number of charge points is low compared to the number of EV drivers, social charging will become important, i.e. encouraging EV drivers to move their EV away from a charge point when the EV is sufficiently charged.

- **Smart charging and vehicle-to-grid.** EVs have the potential to contribute to load balancing via smart charging and vehicle-to-grid. Not only should protocols support these functionalities, it is also yet unclear which type of party should receive what data (e.g. CPOs, MSPs, grid operators, energy companies or the car itself) and which business models will arise.

- **Electrifying other modes of transportation.** Currently, a lot of attention is paid to electrifying the passenger fleet, but there is also a lot of potential in electrifying other modes of transport such as distribution services and public transport. It is not clear how this will affect roaming, because many of these modes of transport will charge at their own company.

- **Better price transparency.** In the current situation there is not much price transparency. It is expected that this topic will become more important when EVs become more mainstream, because it will become a bigger concern of governments and consumer associations.

3.2.2. Mix and number of parties from different sectors

One of the interesting aspects of EV charging infrastructure is that it is an emerging market in which parties from several big industries entering the market. Energy companies and grid operators have an obvious interest in the field, i.e. supplying energy and managing the grid, but also traditional oil companies have entered the market via take-overs (e.g. Shell has taken over NewMotion, British Petrol has taken over Chargemaster, Total has taken over
Pitpoint, ENGIE has taken over EVBox). Furthermore, OEMs are expected to invest more in charging infrastructure. Tesla is an obvious example, but traditional OEMs such as Renault and BMW have also moved towards the market. Software companies will probably play a role in software and data management, but it is unclear whether this will be a big role, since many MSPs and CPOs already have their own IT team. Some CPOs are also back office providers, providing IT and administrative services for other CPOs and MSPs (Greenflux, Last Mile Solutions, EVBox). Another uncertain factor is whether there is still room for startups in the market, given that many of the necessary roles are already fulfilled, and it is likely that MSPs and CPOs will offer full service packages. Finally, some interviewees thought that the future of roaming hubs is unsure, because it is not certain they will continue to add value to a market that moves to further standardization. If this turns out to be the case, they could remain relevant by focusing more on clearing services or aggregator services for smaller companies and startups. Application of block chain technology can also decrease the need for large roaming hubs, because it potentially enables a hybrid roaming system without centralized entities, in which small, cheap, and easy to set-up roaming hubs can fulfill services such as administration and billing.

There were disagreeing views on the number of parties that will be active in the EV charging infrastructure of the future. A commonly held notion was that there are too many parties active now compared to the market size, and there will be a market shake-out in the coming years with only a few large parties remaining, though there may still be room for smaller, specialized companies. While none of the interviewees had real concerns about this, one interviewee highlighted that the EU should watch out that the EV charging infrastructure does not become a vertically integrated sector as has happened with traditional automotive for instance. However, two interviewees pointed out that the effort of building up the charging infrastructure for Europe’s ambitions for electrifying transportation, that a large number of parties will be needed to make this a reality. The interviewees all expressed uncertainty in their predictions, as the field is rapidly developing and there might be a struggle for market power by companies that have large amounts of capital available for investments. Another factor that makes predictions hard is that the type of parties will depend on local conditions; in Europe, energy companies play a large role in the market, while in the United States of America new entrants are more dominant. There are also differences within Europe. For example, in the Netherlands only a few parties are active in charging infrastructure, while in Germany and France local grid operators play an important role.

3.3. Pathways to interoperability

Under this item we discussed pathways to interoperability of charge points. All interviewees saw interoperability as a crucial aspect of the future of EV charging infrastructure. One interviewee pointed out that interoperability has to be achieved for three elements: (1) charge points with EV connectors, (2) payment systems of charge points with EV users, and (3) charge point information systems (e.g. for location of charge point). Perspectives diverged on how interoperability could be achieved. We discussed several scenarios for achieving interoperability, and what the role of large SSOs such as IEC and the International Organization for Standardization (ISO) should be in setting a standard for EV roaming.

3.3.1. Scenario 1: One single standard: harmonization of protocols

One scenario for achieving interoperability worldwide is that the existing protocols are harmonized into a single internationally accepted protocol. Most interviewees agreed that having a single standard is beneficial for the sector, because updates in the protocol do not have to be compatible with the other protocols and gateway technologies, and roaming hubs do not have to implement multiple roaming protocols. Some interviewees argued that this scenario will stimulate innovation in the sector. Moving away from competition on protocols and from binding customers to hubs will allow the sector to compete on other services for the user, and will reduce pricing because the ‘middle man’ (hubs) will not be essential for roaming, which will benefit EV drivers. However, others argued that competition on protocols is beneficial for the sector, because this will stimulate protocol developers to add new functionalities and hubs to compete on low pricing.

The interviewees differ on their view on whether this scenario is likely. An often heard argument is that there are too many parties that have a vested interested in keeping their own protocol. Either because they have already implemented it and know how to work with it, or because, for the hubs, their business model depends on customers making use of their protocol, which could be described as a lock-in situation. If the roaming hubs do not have their own protocol the customers more easily switch between parties offering roaming services. Other interviewees, while acknowledging this scenario is difficult politically, think that it will happen on the long term because it is
cheaper. One interviewee said that the merging of protocols could go very slowly and almost unnoticeable. Some interviewees see a role for regulation in making this scenario happen.

3.3.2. Scenario 2: One single standard: winner scenario

One of the existing protocols could become dominant through widespread market adoption. Once one protocol is dominant, many parties will want to switch that protocol because of the advantages of one single standard. An advantage that was named for this scenario as compared to a merging of protocols is that a merging process probably requires the involvement of a governmental body, while the market tends to make more pragmatic choices than governments. A disadvantage of this scenario is that there is a risk that a sub-optimal protocol is selected by the market. Several interviewees saw this as the most likely scenario. Variations on this scenario are that there will be two or three dominant protocols worldwide, or that the government steps in to select a winning protocol, as has happened with EV connectors ofcharge points.

3.3.3. Scenario 3: Multiple roaming protocols connected by gateway technologies

In this scenario, multiple protocols co-exist and interoperability is achieved by connecting those via gateway technologies, i.e. systems that interface with two or more different protocols to the best degree possible. This is also reflects the current situation; the roaming hubs are cooperating with each other and the OCPI management to establish gateways between the protocols. Some interviewees pointed to the benefits of a gateway scenario. Aside from the potential competition on costs and functionalities, as discussed in Section 3.3.1, gateways may also have the benefit that it will be easier to connect different sectors and countries to the charging infrastructure according to one interviewee. Disadvantages of this scenario are the costs and complexities associated with updating protocols and gateways due to compatibility concerns. Additionally, with gateways you might not be able to use all the functionalities of the protocols. Furthermore, one interviewee argued that this scenario will have lower price transparency for the consumers as compared to having a single standard, and that the charging infrastructure will be less stable because of errors in translating data from one protocol to the other. Several interviewees saw this as the most likely scenario because they see the EV field as too diverse to all adopt the same protocol. Another reason why this scenario might happen is because the number of players gets very low, and these players connect peer-2-peer via their own, proprietary protocol, which easily integrates with their back-end system.

3.3.4. Scenario 4: No roaming

It is a possibility that full roaming will not be achieved, and that parties follow the Tesla model for charging infrastructure, in which an OEM only provides access for their own customers. This is not seen as likely because many parties benefit from interoperability and legislators find it important too. Another situation that might arise is that there would be no interoperability via roaming protocols, but through ad hoc payments. This could happen if the costs for roaming (either via hubs or peer-2-peer) become too high, because not many EV users roam. This scenario was also not seen as likely, because it is expected that even if EV users will roam relatively less than now, the total demand for roaming will increase because the market for EVs is expected to increase dramatically. Furthermore, trends in mobility such as mobility-as-a-service, car sharing, leasing, and autonomous driving favor a roaming approach. Still, some interviewees thought that if cheap ad hoc payment systems, for instance based on mobile phone apps, the market might still move to ad hoc payments as many consumers will prefer this option over roaming contracts.

3.3.5. Standard Setting Organizations

The currently used roaming protocols were developed locally and bottom-up by relatively small organizations. A top-down approach would be to develop roaming protocols in large SSOs. The IEC has started developing a roaming protocol (IEC 63119), which may be market-ready in a couple of years. However, it is unclear whether this protocol will be widely adopted, or that parties will stick to their own, already implemented protocols.

Concerning the question whether management of current roaming protocols should be transferred to large SSOs, most interviewees named the same advantages and disadvantages of making such a move. The perceived advantages are the international recognition that comes from such SSOs, and that countries can refer to such standards in national legislation. The perceived disadvantage is that the development will be slower and it takes a lot of investment to become part of a working group. One reason that development is slow is the need to reach
consensus, which is very difficult with parties from all over the world that have their own view on how the EV market should work. With the EV market developing fast, slow development of communication protocols is not desirable, since the protocols would not be able to timely facilitate new demands of the market. An additional concern that was raised is that there should be a bigger effort in involving countries outside of North-West Europe in roaming protocol development. On a different note, one interviewee pointed to an advantage that SSOs have besides as a way to develop a standard. While this interviewee thought that the development speed of a standard for EV roaming is too slow in large SSOs, the working groups can give a lot of insight in the concerns of different countries and industries and thereby facilitate knowledge exchange through discussing ideas, current issues and use cases.

The difference in views among the interviewees were on the weighing of the advantages and disadvantages and the timing of when to bring the roaming protocols to a large SSOs, as they thought the protocol should be more mature before making this move. One interviewee pointed out that bringing these protocols to a large SSO will slow down development, but that because of this reason it would be good to start that process now, so that by the time EVs are mainstream there is already a well-functioning and widely adopted roaming system in place. Though the other interviewees recognize the latter point, they think this should be achieved in a different manner, with smaller management organizations. Another issue that was raised is the risk is that standards from large SSOs are more like certificates for security than real security, because it is more difficult to have a close look at how security is incorporated in the standards. Most interviewees thought that on the long term, when the EV market has reached maturity, it is a good idea to bring the protocols to SSOs. As a counterargument, one interviewee stated that you will never know when the EV market is mature, and that therefore bringing a roaming protocol to a large SSO will never be a good idea. This interviewee added that the involvement of large SSOs is unavoidable, but that aside from these efforts there is no problem that other protocols can be continued to be developed independently, because the EV field benefits from the diversity of protocols.

4. Discussion and future work

Our results highlight the importance of attitudes towards roaming protocols and the context in which they are used. Several of our interviewees have implemented multiple roaming protocols, because they want to offer access to a large network of charge points to their customers. While the protocols differ on a technical level relevant for implementation, they are very alike in functionalities offered, and no interviewee had a clear preference for one protocol over the other because of technical performance. Instead, preferences for a specific protocol are often based on how and by whom the protocols are governed. Some parties like the open and collaborative governance of OCPI, while other parties appreciate the services offered by the roaming platforms and use their protocol to connect to them. Furthermore, some parties continue using a specific protocol for legacy purposes, because it takes effort to switch to a different one.

The context of the EV charging field matters in several ways. Firstly, there is a strong expectation that firms from a wide variety of backgrounds will cooperate in EV charging infrastructure, and will need to be connected via roaming protocols. Secondly, we have seen the legislation on roaming differs between countries. Not only whether legislation on whether it is mandatory to connect to a roaming platform, but also on how legislation on topics like CDRs and calibration of measurement equipment must be handled within the protocols. Thirdly, the EV field is developing fast. New functionalities might be needed in the future and new market roles may arise. While for some interviewees this meant that the best situation would be to have one protocol, which can be updated quickly without having to be compatible to other protocols and gateways, others preferred having multiple protocols that compete on functionalities offered. One thing almost every interviewee agreed on is that large SSOs have a development process that is too slow for the fast developing EV market. Even so, the IEC has already started developing a roaming protocol intended to become an internationally excepted standard for roaming in EV charging infrastructure. Fourthly, whether roaming hubs remain viable depends on how many parties are dominant in EV charging infrastructure in the future, which in turn might vary between countries. If there is a big consolidation round, the few remaining firms might not want to be dependent on roaming hubs, and instead connect peer-to-peer with proprietary protocols. Finally, the attractiveness of roaming depends on the charging behavior of EV drivers in the future, which in turn is dependent on charging infrastructure and battery size. If fast chargers become very popular EV drivers might predominantly use fast charging infrastructure offered by a single firm. If battery sizes become very large EV drivers might predominantly charge their EV at home or at work. Both these cases will reduce the need for roaming of EV drivers, and ad hoc payments might suffice to connect to charging points.
The views of the interviewees diverged most on the topic of what pathway to interoperability is most feasible and most desirable. The discussed pathways included harmonization of protocols, gateway technologies, a “winner” scenario, and no roaming. Except for the no roaming scenario, for every pathway there were several interviewees who saw it as the most likely one to happen on the long term. Looking at the near future, all interviewees agreed that the merging of protocols is not likely to happen, because it is too difficult to achieve politically. The business model of the roaming hubs depends to a large extent on having their own protocol, because they can offer unique value to their customers. Indeed, two interviewees speculated that roaming hubs might become obsolete in the future if there will be one, widely adopted roaming protocol. Several of the interviewees thought moving to a single standard will happen in the long term, either because the gateways become too costly and complicated or EU legislation will force the sector to move to a single standard. Another pathway to a single standard is the winner scenario, in which one protocol dominates the market, making it attractive for parties to implement that particular roaming protocol. Our results thus do not provide a clear answer on what the optimal pathway to achieve interoperability is, but instead emphasize the diversity of views, expectations and interests of stakeholders in the dynamic EV charging field and uncertainty in how roaming will be organized in the future.

This paper reports the results of 32 interviews. We believe that our sample covers the most important stakeholder types, and we have been able to highlight a variety of perspectives on roaming. So far, we have not reached theoretical saturation in our interview; there are still new perspectives coming up in additional interviews. In the continuation on our project, we will complement our sample with interviews from outside the Netherlands. Our results show that local context matters, so we expect to still find fresh takes on roaming. The situation around roaming in the Netherlands has been quite exceptional, as the sector from an early stage has decided to work on interoperability together. We expect that we can better understand what the reasons are that roaming is not in place despite the mutual benefits roaming can offer to the involved stakeholders. Furthermore, we also want to interview stakeholders not directly involved in e-mobility, such as legislators and standardization bodies, which are expected by some of our interviewees to play an important role in how roaming will organized. Additionally, we aim to interview people from other sectors such as telecommunications where standards for roaming have been developed, to be able to do a comparative study. This will allow us to better understand the different considerations of trade-offs between having a single protocols and gateways as highlighted in this paper.

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