evRoaming4EU

Realising cross-border charging in Europe

Design principles for an 'ideal' EV roaming protocol

Report D6.3 for the evRoaming4EU project

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1. Objective of the evRoaming4EU project and Work Package 6 on achieving interoperability

This report is part of the Work Package 6.1 of the evRoaming4EU project. Section 1.1 introduces the overall project, Section 1.2 discusses the context, funding and consortium for the project, and Section 1.3 introduces the role of this specific report.

1.1 The evRoaming4EU project

The main objective of evRoaming4EU is to facilitate roaming services for charging Electric Vehicles (EV) and provide transparent information about locations and rates of charging in Europe, by making use of an open independent protocol. This will be demonstrated through regional and transnational pilots in four different regions, thereby promoting the creation of one European market for EV drivers and related products and services.

The project works towards two distinct goals. The first goal is maximizing interoperability of the EV charging market, especially the ability of different charging infrastructures to communicate with each other in an efficient manner either via a single protocols or multiple interoperable protocols. The second goal is to maximize adoption of a harmonized EV charging protocol, i.e. the number of parties using the protocol. The results of the project should give insight into how these goals can be achieved, and where trade-offs of achieving these goals have to be made.

More information is available on www.evroaming4.eu.

1.2 Project context, funding and consortium

The evRoaming4EU project is an EMEurope Research and Innovation (R&I) project. Electric Mobility Europe[1] is set up by 9 European national and regional government-related organisations with a strong interest in advancing electric mobility in Europe. It is an ERA-NET Cofund under the EU Horizon 2020 programme, aiming to further advance electric mobility in Europe and designed to take transnational e-mobility research and policy exchange towards deployable solutions. The evRoaming4EU project is one of the 14 project selected by Electric Mobility Europe Call 2016, and has grant number EME-31.

The evRoaming4EU consortium consists of Copenhagen Electric, Eindhoven University of Technology, E.ON Denmark, ENIO, MRA-Electric, Smartlab Innovationsgesellschaft mbH, Stromnetz Hamburg SNH, and project coordinator The Netherlands Knowledge Platform for Charging Infrastructure (NKL).

1.3 Objective of this report

This document is part of work package WP6 of the project evRoaming4EU. The objective of WP6 is to offer insights on how to achieve interoperability from a standardisation perspective, through a combination of desk research and stakeholder interviews.

[1] See https://www.electricmobilityeurope.eu

The WP explores whether achieving interoperability feasible (and best done) via harmonization of the different existing protocols into an independent internationally accepted protocol. If not, it will explore other options to achieve interoperability (such as 'gateways' that allow translation and interconnection between systems).

In this report, we describe how perspectives on the future of roaming for EVs, based on stakeholder interviews and desk research. From this, we derive design principles for an 'ideal' roaming protocol, 'ideal' meaning in this case that it aims to take into account the interests of all e-mobility stakeholders to ensure seamless roaming for EV users, fits within the regulatory landscape, and allows for efficient use of public charging infrastructure in the EU. Finally, we discuss to what extent the existing EV roaming protocols in Europe fit with this ideal. These are the Open Clearing House Protocol (OCHP), the Open InterCharge Protocol (OICP), the eMobility Inter-Operation Protocol (eMIP), and the Open Charge Point Interface (OCPI).

The aims of this report are:

- Provide an overview of stakeholder perspectives on the future of roaming
- Provide an overview of the regulatory environment relevant for roaming in Europe
- Propose design principles for an 'ideal' roaming protocol
- Discuss the extent to which current roaming protocols adhere to this ideal.

This report is one out of three reports produced in the context of WP6. The other two are:

- D6.1. Comparative analysis of standardized protocols for EV roaming. This report presents a comparison of the major existing EV roaming protocols in Europe. These are the Open Clearing House Protocol (OCHP), the Open InterCharge Protocol (OICP), the eMobility Inter-Operation Protocol (eMIP), and the Open Charge Point Interface (OCPI).
- D6.2 Achieving interoperability in EV roaming: Pathways to harmonization. Here, we present several scenarios for how interoperability for e-roaming can be achieved. For each scenario, we discuss advantages and disadvantages and how it fits within trends in e-mobility.

The rest of this document is organized as follows. Chapter 2 presents our methodology and data sources. Chapter 3 describes an 'ideal' EV roaming system, based on our market research, discusses the regulatory environment in Europe relevant for developing standards for EV roaming, and discusses the integration of e-mobility in the transport and energy sectors. Chapter 4 translates our findings in seven design principles for an 'ideal' protocol for EV roaming. Chapter 5 evaluates to what extent current roaming protocols adhere to our formulated design principles. Chapter 6 summarizes and discusses our findings.

2. Methodology and data sources

This report is based on a combination of desk research and stakeholder interviews. Our desk research allows us to investigate visions for the future of public charging infrastructure and the regulatory environment, while the stakeholder interviews give insight in how various stakeholders see the future of EV roaming. We collected data through desk research (Section 2.1) and stakeholders interviews (Section 2.2).

2.1 Desk research

To investigate visions of public charging infrastructure we reviewed the scientific literature on e mobility. In particular, we focussed on ideas about accessibility of charging infrastructure and how it can be efficiently integrated in existing transport and energy infrastructures. As we expected that significant material might be available only as 'grey literature' (such as conference contributions and reports), we decided to use Google Scholar as our main database for the literature search. In that database, we searched for a set of specific keywords or combinations thereof, and manually decided whether found studies were relevant for our research by reviewing the abstract.[2] We extended our selection of literature with relevant articles from the personal collection of the authors. Furthermore, we used desk research to investigate the regulatory environment in Europe concerning standards for communication systems. We base this part of our analysis mainly on relevant European Union (EU) legislation, on documentation of the World Trade Organization committee on Technical Barriers to Trade (WTO TBT) [14], and news websites covering relevant news websites. Finally, this report compares the EV roaming protocols OCHP, OICP, eMIP, and OCPI to our proposed design principles for an 'ideal roaming protocol', based on protocol documentation and interviews. These four protocols are all published online and freely accessible [1]–[6]. We have analysed the documentation of the most recent versions of these protocols to see which functionalities they support.

2.2 Interviews

We conducted interviews to investigate what different types of stakeholders see as an ideal roaming system. In our selection of interviewees, we sought variety in position in the value chain, which roaming protocols are used, and geographical location. Figure 1 presents a representation of market roles and their relation in the EV ecosystem. The scheme was designed to guide us in our selection of interviewees and to discuss their specific market roles. We do not claim our scheme on the EV ecosystem to be definitive, 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. Yet, we believe this scheme allows to identify a relevant set of stakeholders to approach for interviews. Furthermore, we discussed the scheme with several interviewees, who agreed that it is a good overview of the current EV field.

[2] The (combinations of) keywords we used were: "public charging infrastructure", "e-mobility", "electric vehicle", "business model", "smart charging", "roaming", "standards", and "protocol".

Our interviews were semi-structured, and we sent a summary of the interviews to the interviewees for them to check for potential mistakes in interpretation. We investigated strengths and weaknesses of the current protocols and explored views about the future of EV charging and the role of roaming therein. We asked questions on several topics, see Appendix A for our complete interview protocol. In this report, we only use results from questions 3-6, which discuss the future of e-mobility and advantages and disadvantages of different ways to organize roaming.

We have conducted 35 semi-structured interviews with 38 roaming experts (three double interviews). We approached potential interviewees through the network of the project evRoaming4EU, by asking interviewees to point us to new potential interviewees, and through visiting the electric vehicle conference EVS32 in Lyon, 19-22 May 2019. We have spoken to stakeholders from the Germany (13), Netherlands (13), Austria (3), France (3), Portugal (2), Sweden (2), Belgium (1), and Spain (1). Our set of interviewees covers all the 11 roles introduced in Figure 1, except that of Automotive Supplier. We have approached several Automotive Suppliers to conduct an interview, but all of them declined. Five of the interviewees are experts on EV roaming but not captured in our scheme: two researchers, one consultant, and two representatives from sector interest organizations.[3] Appendix B. List of interviewees presents the names and organisations of our interviewees (except for eight interviewees who participated under the condition of anonymity).

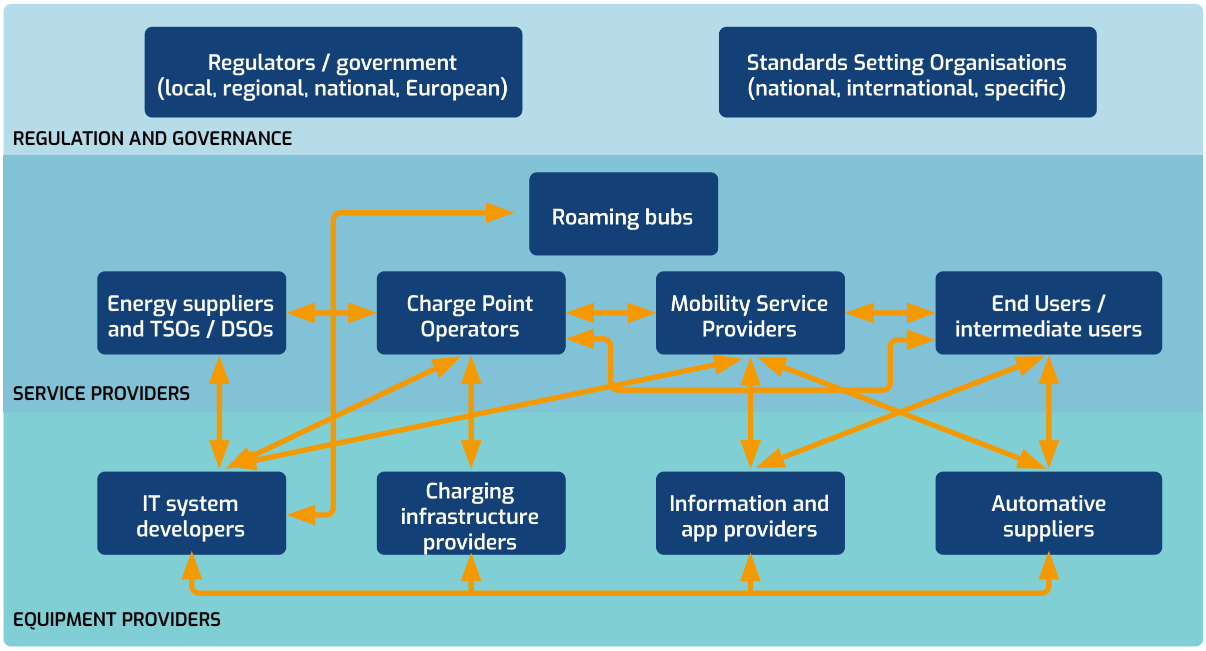

Figure 1. Market involved in the whole value chain roles and connections in the EV ecosystem. Note that we did not draw connections between the regulation and governance level to other stakeholders, since these stakeholders are involved in the whole value chain

[3] Please note that the way we identified interviewees (especially when we used our own networks) may have resulted, to some degree, in an overrepresentation of actors that use OCPI. While we did specific efforts also to include interviewees that used (only) other protocols, their final number is lower.

3. Perspectives on the future of roaming

This chapter describes perspectives on the future of roaming of various e-mobility stakeholders throughout the value chain. We present perspectives for several dimensions: (1) market development (Section 3.1), regulatory environment (Section 3.2), and the incorporation of EV roaming in broader transportation and energy infrastructures (Section 3.3). We base these perspectives on our stakeholder interviews and desk research. From our perspectives, we derive design principles for an 'ideal' roaming protocol in Chapter 4.

3.1 Market development

Our interviewees often characterized the current e-mobility market as not yet mature, and expected a large expansion of the market in the coming years (and even decades). The expected changes in market structure and market volume has implications for protocol design. First, we discuss how our interviewees expect the demand for and supply of roaming services to develop. Second, we discuss how our interviewees think roaming should develop, related to creating a seamless user experience for roaming, flexibility of protocols to incorporate new services and business models, avoiding unnecessary market barriers, and cross-border roaming.

3.1.1 Demand for and supply of roaming services

The demand for roaming services is generally thought by our interviewees to increase, mainly because the number of EVs is expected to increase. While private charge points can cover demand for EV charging to a significant extent, public charging infrastructure will remain important for (1) people who do not have the ability to charge at home and/or at work, (2) drivers who take many and/or long trips, (3) EV drivers with cars with small batteries, and (4) drivers that go on holiday with their EV. Drivers can if course obtain a subscription (services) from one specific Charge Point Operator (CPO), but are then limited to charge point of that specific operator only. They could take subscriptions from multiple CPOs, but this can become rather impractical, especially if there are many such operators. Roaming, allowing a user to use services of 'guest CPOs' without having to obtain a subscription from them, can greatly extend the network of charge points where they can charge.In many ways, this is similar to the concept of roaming as we know it from mobile telephone services, where consumers can use their phones aboard (guest networks) while only having a subscription with their home operator.

An EV driver may also obtain services from a Mobility Service Provider (MSP), which provides such roaming services to the user. Finally, seamless roaming (or seamless interoperability), refers to the situation where a user (EV driver) can charge at any public charge station, regardless of which CPO operates that charge station and regardless of which MSP the user has selected for mobility services and payment.

While the number of roaming transactions is widely believed amongst our interviewees to increase in the future, there is more uncertainty regarding the relative number of roaming charge transactions as compared to the total number of charge transactions. One development that could increase the relative number of roaming transactions, is an increase of the number of EV drivers that depend on public charging infrastructure, because they do not have the opportunity to install a private charge point. (think of people living in cities and that do not have their own driveway.) Larger EV batteries might result in a decrease of roaming demand, EVs are charged sufficiently at home and/or at the office, but may also result in an increase, as more EV drivers will travel internationally. Furthermore, the demand for roaming could decrease if ad hoc payments become more popular for accessing charge points, for instance due to cheaper ad hoc payments systems (e.g. mobile apps) or a strong consumer preference for ad hoc payments,

The number of roaming transaction will depend on not only consumer demand, but also on supply of roaming services by MSPs and CPOs. In several European countries, such as the UK and the Nordic countries, major charging infrastructure networks have – to date – not yet opened their networks for roaming. While some interviewees thought these parties would open their network because of market pressures, others thought the situation would not change, as offering exclusive access to their network is central the business model of these companies.

3.1.2 Seamless user experience

Several interviewees believed that a main challenge for the field is to create a seamless user experience (UX), meaning that roaming should be as effortless and transparent as possible for users. Aspects of a seamless user roaming experience are for example easy access to charge points, clear and complete information provision, easy payment, and transparent pricing.

One of the reasons why developing a seamless UX is important is that many drivers of internal combustion engine (ICE) vehicles are already used to having a seamless UX at gasoline stations, where payments are possible via debit card, credit card, and cash money. E-mobility competes with ICE vehicles, and while some people switch to EVs because they prefer EVs over ICE vehicles, e.g. because they like the technology or out of environmental concerns, EVs are not attractive to many people because of the high costs of EVs and the lower level of convenience. Creating a seamless UX for EV roaming will greatly increase the attractiveness of EVs as compared to ICE vehicles.

A seamless UX for charging at public charge points does not necessarily have to be based on roaming. Some interviewees thought that most consumers prefer ad hoc payments over roaming. In particular, these interviewees thought that ad hoc payments are closer to the current customer experience of paying for fuel at gasoline stations. Also, there are complaints about roaming tariffs being high and not clearly communicated. These interviewees thought that an ad hoc payment system would provide more clarity upfront about how much you will pay for the charging session.

Other interviewees, however, pointed out that having ad hoc payments at EV charge points is really challenging while a country like The Netherlands has only around 4000 gasoline stations, there are currently already over 50,000 EV charge points (7), and this might grow still with an order of magnitude. The challenge here is that, with so many stations, having ad-hoc payment (for instance having to install a payment terminal) places a considerable APEX and OPEX burden on the CPO.

3.1.3 Flexibility to incorporate new services and business models

Several interviewees stated that roaming protocols should allow for the flexibility to incorporate new applications in the roaming communication infrastructure. E-mobility is developing rapidly, and there is no consensus yet on what is the most efficient way to organize charging infrastructure. Business models for EV charging are still developing, and have to consider many factors, including the availability of technology, billing, accessibility, user behaviour, mechanisms for funding, and opportunities for new revenue streams [8]. Over time, the e-mobility market has grown to be complex, with a long value chain with many roles (EMPs, CPOs, intermediate parties, etc.) [8]–[10]. This requires alignment of processes on all ends, which leads to various challenges for roaming. One of the major challenges for roaming protocols is to achieve this alignment while keeping a high degree of flexibility to incorporate new services and business models. To facilitate this flexibility, the communication standards should be openly accessible for anyone, at least to the highest degree possible.

During the interviews, many potential new services and business models were discussed that would have to be supported by roaming protocols. Examples of often-discussed new services are the incorporation of identification-by-car through ISO 15118, smart charging, vehicle-to-grid, and providing information on the area surrounding a charge point. Several interviewees thought that offering full-service packages to customers (e.g. including an EV, a charge point, energy contract, a roaming contract, and other additional services) will become a popular business model in e-mobility. Furthermore, there are several relevant trends in the broader field of mobility, such as autonomous driving, car sharing, and mobility-as-a-service. All these developments will have implications for how charging infrastructure is best organised, and underline the importance of setting up a flexible core communication infrastructure.

3.1.4 No unnecessary market barriers

Several interviewees stated that in a well-functioning roaming system, there should be no unnecessary barriers for new parties to enter the market. Furthermore, many interviewees expect that e-mobility will benefit greatly from start-ups with novel ideas entering the market, as there is still a search for how to optimally organize charging infrastructure. Current barriers to provide roaming (in certain regions) for CPOs and MSPs are (1) not enough technical resources to implement roaming protocols, (2) not enough resources to provide charge point information of sufficient quality, (3) not enough resources to establish roaming contracts, and (4) high roaming fees. An ideal roaming system would reduce these barriers as much as possible.

3.1.5 *Cross-border roaming*

All interviewees with whom we discussed cross-border roaming, thought that it is very important to realize it, at least within Europe. While a global roaming system was often seen as ideal, some interviewees thought that such a global system would not be necessary, and not feasible because of too large cultural/market/context differences. These interviewees argued that a roaming system at regional level (e.g. Europe) would suffice for most EV drivers. One interviewee pointed out that while for most individuals and local companies, roaming at European scale would be fine, many multinational companies want to be able to operate EV fleets on a global level. The demand for global roaming of these companies could lead to a global roaming system to develop.

One interviewee stated that a difficulty with developing global roaming systems is that developing countries are not involved in developing standards for e-mobility, or only to a very limited extend, because these countries have only small EV fleets. They have not adopted current standards for EV roaming, and this makes it difficult to take the needs of developing countries in consideration in developing standards for roaming. The interviewee stated that more effort should be put into involving developing countries in the standardization process, even though it was acknowledged that this might be hard to do because of a lack of interest of developing countries to contribute.

3.2 Regulatory environment

The European Union wants to stimulate the electrification of transportation, as it contributes to the goals of CO2 reduction set in the Paris agreement [11]. However, there are no European-wide regulations on charging infrastructure; the relevant regulation is implemented on national and local level. National governments have implemented a variety of policy measures, which include setting of national targets, subsidizing public charging stations, and information campaigns [12], while municipalities are typically the governmental level at which charge point placement is decided [13]–[15]. The lack of central EU coordination may have been a factor in the fragmentation of charging infrastructure in Europe [16]–[18]. Examples of this fragmentation are the means of payment for ad hoc access to charging infrastructure, and the variety of plugs used to charge EVs – e.g. the IEC 62196 Type 2 connector (a.k.a. 'Mennekes' plug) and the IEC 62196 Type 4 connector (a.k.a. 'CHAdeMO' plug). So far, regulation has not played an important role in the development of roaming protocols. Several interviewees expected that governments may want to play a bigger role in the future as the e-mobility market grows, and charging infrastructure becomes critical infrastructure. The below subsections discuss several aspects of the regulatory environment in Europe relevant for roaming, based on our interviews and desk research. More specifically, we discuss regulation regarding ad hoc access and access via hubs, national access points, calibration and measurement law, fiscal regulation, standards, and data protection.

3.2.1 Ad hoc access and access via hubs

The Directive 2014/94/EU on the deployment of alternative fuels infrastructure (AFID) [19] states that charging point operators should offer charging services on an ad hoc basis. The directive does not state in what manner ad hoc access should be provided, which has led to different payment mechanisms in use including cash, debit or credit cards, Radio-Frequency Identification (RFID) cards, mobile phone apps, and SMS payments [16]. The directive also stipulates that, in addition ad hoc access, costumers under contract of one charge point operator may (sic) be allowed to charge at any other operator.

Several countries require (partly) publicly funded charging infrastructure to allow for roaming. An example is Germany, where publicly funded charging infrastructure should be connected to a roaming platform, although parties are free to choose to which roaming platform they connect. It is uncertain whether this regulation will hold, as there is a lobbying effort against this regulation by parties who consider it discriminatory. In France, the legislator has a preference for connecting through roaming platforms, because this guarantees that a CPO is open to any MSP, though this is not required. In Portugal, it is mandatory to connect via the roaming platform MOBI-E, and bilateral roaming is not allowed.

The interviewees disagreed on whether regulators should require one single means of access. One interviewee was a proponent of requiring access at least via credit and debit cards, and another preferred regulation to require a roaming connection of each public charge point. An interviewee who works for a governmental organization thought that governments should harmonize the definition of ad hoc payments, without defining the means of access. According to this interviewee, the question of what means of access to use should be left to the market, because the regional differences in what works best are too large. Two other interviewees made similar arguments against harmonization of means of access, emphasizing that there are differences between countries regarding what people use for payments (e.g. in Sweden mobile apps are popular, in Germany credit cards are unpopular). Another interviewee was against requiring ad hoc access through credit and debit cards, as installing a payment terminal at each and every EV charge point was considered too expensive compared to profits.

3.2.2 National Access Points

Various European countries are setting up "National Access Points (NAPs)" containing data about charge points for EVs. The aim of these is to *"to facilitate access, easy exchange and reuse of transport related data, in order to help support the provision of EU-wide interoperable travel and traffic services to end users."*.[4] The data itself can be stored and made available in various forms, such as a database, data warehouse, data marketplace, repository, register, or web portal.[4] Such data sets could include charge point information (e.g. location, technical specification). The European Commission publishes a list of National Access Points for the various member states [20].

[4] https://ec.europa.eu/transport/themes/its/road/action_plan/nap_en

This list shows the state of the art of the deployment of the National Access Points across Europe, within the scope of the implementation of four distinct delegated acts adopted under Directive 2010/40/EU. Several interviewees thought that European legislation will increasingly demand the integration of charge point data in NAPs. One interviewee stated that to build such a database, there needs to be one single management organization, and the codes used for charge point IDs need to be standardized.

The interviewees differed on their opinion on regulation requiring NAPs. While some thought it would help in building on interoperable charging infrastructure, others thought there is too much focus on creating NAPs (thereby taking away focus on either aspects of developing charging infrastructure), or pointed to some disadvantages of NAPs. One interviewee stated that NAPs do not help much for enabling roaming or other innovative services, as NAPs typically require only information on charge point location and availability status. This interviewee also argued that NAPs require CPOs to provide location data for free, even though this is proprietary data for which CPOs should be compensated if they share it. Another interviewee thought that if NAPs become easy to use this would threaten the hub model, as one of the services hubs currently provide is sharing such data.

3.2.3 Calibration and measurement law

Calibration and measurement law relates to regulations concerning the measurement equipment ('meter') used for billing. Several interviewees discussed Eichrecht, the German calibration and measurement law [21], which they considered the most strict law on this issue, and very relevant for roaming protocol development. Eichrecht requires that, for selling electricity, a periodically calibrated measurement device is required to assure a reliable transaction.

One German interviewee elaborated on several challenges that Eichrecht poses for managing charging infrastructure. Calibrated measurement devices for AC are available and reasonably priced, but calibrated measurement devices for DC chargers do not exist, because there is so little demand for them that developing them would not be profitable. German regulators have become aware of this problem, and are looking into alternatives. A potential alternative is to measure the AC side of the charge point, and subtract 20% as an estimate for transformation losses. But this method is not always accurate and will reduce transparency, which might lead to customers paying too much for a charging session. Another issue is that Eichrecht requires that you must be able to check whether you were billed correctly for a charging session. Realizing this is tricky for charging infrastructure, as charge points are used by many people, so you cannot use a single meter per consumer, and instead the individual transaction must be securely stored. One proposed solution is that charge points should have a USB connection through which EV drivers can retrieve the data directly after the charging sessions. Another potential solution is that the transaction data is stored in the charge point, and consumers can go back to the charge point to retrieve the data.

However, this might a lot of effort for consumers who do not live or work close to the charge point in question. A workaround for these issues could be to base session fees not on kWh charged, but on connection time or another sort of price scheme. However, according to German law you are only allowed to sell electricity by charging per kWh. According to one interviewee, strictly following Eichrecht leads to a non-workable situation for e-mobility. There are active lobbying efforts going on against applying Eichrecht to charging infrastructure. Another (non-German) interviewee recognized that Eichrecht poses many challenges, but thought that solutions could be found which would then be interesting for other countries to follow.

3.2.4 Fiscal regulation

Based on our interviews, we identified two relevant aspects of fiscal regulation for cross-border EV roaming.

The first is whether charging an EV is classified as 'providing a service' or, in contrast, as 'selling energy'. For providing services, there is a clear framework for international trade, but for selling energy, this is not the case. This makes selling energy particularly difficult to private customers abroad. In Germany, this issue is currently solved by classifying the charge point as the end-customer, not the EV driver. This way, the party supplying the energy to the chargers, usually the CPO, will have to take care of the energy tax. This is an exception made by regulators for e-mobility. The classification issue is further complicated by different stances on it among European countries. In Germany for instance, EV charging is classified as selling energy, while in France a law is announced that classifies EV charging as a service. This issue is discussed in working groups at European level, which, according to one interviewee, increasingly tend towards classifying EV charging as energy supply. However, this discussion has not been settled yet.

The second issue in fiscal regulation is that it is unclear whether Charging Data Records (CDRs), which currently form the basis of roaming transactions, are recognized as an invoice by tax authorities.

3.2.5 Standards

A relevant aspect of the regulatory environment for EV roaming is the degree to which this environment does make the use of specific standards compulsory. From a regulatory perspective, most countries around the globe consider standardisation primarily as a voluntary mechanism, both in terms of the use of standards, and participation in the development and setting of standards. The Committee on Technical Barriers to Trade of the World Trade Organization's [22] established that for a standard to be 'open', it should, amongst other things, be accessible for at all interested parties, and that any party with an interest in a specific standardization activity should be given meaningful opportunities to participate at every stage of the standard development.

Normally, any party is, in principle, free to decide whether to use a particular standard (or chose the standard to use if there are multiple options) and free to decide whether to engage in the standard setting process. In most European countries, binding references in law or regulation to specific standards (also called 'de-jure standards') are rare but do sometimes exist at the national level.

The role of standards in creating a common market has been early recognized in Europe, by the European Economic Community (EEC, established 1957), later resulting in the European Committee (EC) and the European Union (EU). Initially, the EEC and EC set many specific, technical specifications in its legislation in an attempt to harmonise many of the European markets for products and services. Gradually, it was realised that such detailed rules were undesirable, as well as very resource-intensive. In the mid-1980s, the so-called New Approach to standards was introduced. This new approach was based on four fundamental principles. In short, these principles are as follows: (1) Legislative harmonisation should be limited to the adoption of (more abstract) 'essential safety requirements', (2) European standards organisations are entrusted with the task of drawing up harmonised standards for products that conform to these essential safety requirements, (3) these harmonised standards are not compulsory and maintain their status as voluntary standards and (4) national authorities are obliged to recognise that products manufactured in conformity to these harmonised standards are presumed to conform to essential requirements [23]. Currently, there are three European Standards Organisations (ESO) formally recognized by the EU (CEN, CENELEC, and ETSI) [24]. A process in which ESO's are requested by the European Commission to initiate a technical standard in the context of the New Approach is known as 'mandating' (not to be confused with an obligatory standard which some might call a 'mandated standard').

While one could assume that the New Approach leaves parties entirely free in terms of the use of standards, it has been argued that this is not fully the case [25]. While standards developed by ESO's are automatically assumed to meet the essential requirement (see point 4 above), it can be very hard for other standards to proof their necessary compliance with these requirements, thus giving ESO standards a strong comparative advantage over other standards.

In interesting deviation from the voluntary principle can recently be observed in Europe and is actually in the field of mobility. Around 2010, there were different charge plugs for electrical vehicles in use in Europe, all confirming to the international standard IEC 62196-2 (which defined three plugs, not just one). Amidst concerns over fragmentation, the European Commission mandated CEN to standardize one single plug, in line with the New Approach. When that process was delayed, the Commission wanted to end uncertainty in the market and announced one specific plug, known as "Type 2" as the common standard for the whole of Europe [26].

This announcement was implemented in law in 2014 in Directive 2014/94/EU, which stipulates that both normal and high power recharging points for motor vehicles, *"shall be equipped, for interoperability purposes, at least with connectors of Type 2 as described in standard EN 62196-2"* [19].[5] Even more recently, a second deviation from the voluntary principle manifested itself, again in the field of mobility. For vehicle-to-vehicle communications, known as 'Cooperative-Intelligent Transport Systems' (C-ITS), in March 2019, the European Commission issued a proposal that would make the ITS-G5 standard compulsory for cars [27]. This is a standard based on the IEEE 802.11 standard (usually referred to by the name of its certification scheme WiFi) and standardized in Europe as ETSI EN 302 663, and in the US known as WAVE or DSRC. It has support from Volkswagen, Renault, Toyota, MAN, Scania, and NXP Semiconductors, among others [28], [29]. By doing so, it opted not to choose for C-V2X standard, backed by Audi, BMW, Daimler, Ericsson, Huawei, Intel, Nokia, and Qualcomm, among others [30]. In April 2019, the European Parliament backed the Commission's proposal [31]. Yet, in August 2019, at the last step before formal adoption, the European Council rejected the ratification of the act, reportedly after significant lobbying [32].

In sum, we conclude that whereas in the current regulatory framework in Europe (and most other developed countries around the globe), the use of specific standards is voluntary. However, standards developed standard-setting organizations formally recognized by the European Union (i.e. CEN, CENELEC, and ETSI) do have competitive advantages over other standards. Moreover, in recent years, we observe the first cases in which the European legislator makes the use of some standards obligatory, specifically in the field of mobility.

3.2.6 Data protection

The exchange and storage of personal data for EV roaming should be secure and compliant with the General Data Protection Regulation (GDPR) [33]. The GDPR is the European regulation on data protection and privacy within the European Union. The GDPR requires processes for the exchange of personal data for economic activities to provide safeguards to protect the data, such as pseudonymization and anonymization. Furthermore, it states that personal data can be processed only if it is done under one of six lawful bases, which are (1) consent, (2) contract, (3) public task, (4) vital interest, (5) legitimate interest or (6) legal requirement [33]. The GDPR also requires transparency towards persons whose data is collected regarding which data is collected, at what legal basis and purpose, how long the data is retained, and whether it is shared with third parties. Data subjects have the right to request a copy of the data and to have the data erased under certain circumstances. Furthermore, businesses are required to report on data breaches if these endanger user privacy within 72 hours to national authorities.

[5] The European standard EN 62196-2 covers the same content as the global standard IEC 62196-2, discussed above

There are two major reasons secure data storage is important for e-mobility. Firstly, data of charging sessions includes personal information that could be traceable to an individual. Secondly, if subscription data of an EV user gets stolen, then the thief could use it to charge vehicles while the bill would go to the victim of the theft. While governments have, in practice, not been heavily involved in the security of roaming protocols, several interviewees thought that they will get more involved as the market is growing.

One interviewee stated that the current roaming protocols are not secure enough because they do not have end-to-end encryption. Also, current protocols do not use (electronic) signatures (which ensure that you know where the data is coming from and has not been tampered with). One of the reasons that this has not been included so far is that different stakeholders have different ideas about security in the protocols and ID cards. Furthermore, not every supplier uses the most recent version of the protocol that includes a signature field. Another interviewee mentioned that data is easily stolen from RFID cards, which are currently often used for means of access. It thus seems likely that security will remain an important issue in the coming years for e-mobility and roaming.

3.3 Integration in broader infrastructures

E-mobility and charging infrastructure interact with other infrastructures, such as those for transportation and electricity distribution. The organization of these other infrastructures is also undergoing significant changes, with the rise of new business models, the development towards so-called smart mobility and smart grids, and the transition to sustainable transport and energy systems, among others. E-mobility is envisioned to play a central part in releasing sustainable transportation [34], [35] and in smart grids as well [36]–[41]. This section provides further detail on the integration of E-mobility and charging infrastructure with these other infrastructures, based on our interviews and on academic literature.

3.3.1 Integration with transport sector

There are a number of trends in mobility that are expected to have a great impact on mobility systems in the future. For example, the rise of business models such as car sharing [35], [42]–[44] and mobility-as-a-service [45] – which can include EV charging part of a total bundle offered by an intermodal mobility provider – may lead to a lower ration of privately owned cars. A trend that could become dominant on the longer term is autonomously driving vehicles [46]–[48]. For such vehicles, roaming-based charging fits much better than ad-hoc payment charging, as autonomous vehicles are unlikely to include systems enabling ad-hoc payments. To facilitate roaming for EVs for emergent business models and technologies, the roaming protocols may need to include additional data fields and roles within the e-mobility system.

3.3.2 *Integration with electricity grid*

An efficient charging infrastructure will maximize efficient use of the electricity grid, and minimize unintended side-effects or negative impact. Ig users would engage in 'uncontrolled charging', a massive switch to e-mobility would require great investments in the grid, as peaks in EV charging demand typically coincide with peaks in household demand [49]. The pressure on the grid can be alleviated by technologies such as smart charging and vehicle-to-grid.

Smart charging means that charging point adapts its charge power on electricity network conditions, such as load on the network or power supply from decentralized energy sources, see e.g. [36]–[41]. If necessary, the power output of the charge point can be lower than its maximum power output, or even reduce to zero. Functions of smart charging include load balancing and integration of intermittent renewables in the electricity network. These functions are relevant for grid managers, including both distribution system operators (DSOs) and transmission system operators (TSOs), since peaks on the grid due to EVs charging can be alleviated, and EVs could even contribute to grid management by shifting charging demand. The costs saved on grid management could be used to reduce electricity prices for EV drivers. Furthermore, EV drivers with strong environmental values may want their EV being charged with as much renewable energy as possible. Typically, smart charging scenarios assume automated smart charging, based on price incentives.

Vehicle-to-grid goes one step further than smart charging, as energy can be extracted from the EV at moments when this is beneficial for grid management – for instance during high electricity demand close to the charging station or during black-outs; see e.g. [41]–[43], [50]–[57]. EV drivers could enjoy reduced charging fees or even earn money when making their EV available for vehicle-to-grid services. Similar as with smart charging, vehicle-to-grid scenarios typically assume automated smart charging, based on price incentives.

Smart charging and vehicle-to-grid require charging infrastructure operators to communicate real-time with EV drivers as well as grid operators. Roaming protocols should enable communication between grid operators, CPOs, MSPs, and EV users regarding smart charging, vehicle-to-grid, and pricing dependent on grid conditions.

4. Design principles for an 'ideal' EV roaming protocol

This chapter suggests seven design principles for an 'ideal' EV roaming protocol, based on our study. In the previous chapter, we described the future of EV roaming, the regulatory environment, and connection of charging infrastructure to other infrastructures as found in our interviews and desk research. We showed that e-mobility is a rapidly developing field, characterized by uncertainty in terms of the business models will become dominant, the services are needed, and the future role of regulation. Furthermore, we identified the need for interoperability amongst countries and the energy sector. Based on these observations, we suggest seven design principles for an 'ideal' EV roaming protocol to adhere to. At the centre of our argument is that there is a lot of uncertainty about the future of e-mobility, but at the same time a high need for interoperability of charging stations. We suggest a roaming protocol that aims to be the standard for roaming to provide minimum core functionalities, but also be flexible and open to ensure that new functionalities can easily be integrated in the existing protocol. The rest of this chapter describes the seven design principles, which are (1) inclusion of core functionalities, (2) architectural openness, (3) use of options, (4) scalability, (5) quality control, (6) open standard, and (7) business model agnostic.

4.1 Inclusion of core functionalities

We suggest a roaming protocol to provide some core functionalities that enable seamless roaming for EV users. Based on our desk research and interviews, we identify the following core functionalities:

- **Identification of EV users**
  The identification should be possible in multiple manners, e.g. RFID card, plug-and-charge, bank card, mobile app, etc.
- **Authorization of charging sessions**
  Authorization of the charging session, either offline (e.g. via whitelist) or online.
- **Recording charging session information**
  All relevant information should be logged, such as connection time and energy charged. The measuring of energy changed should satisfy national calibration laws where relevant (e.g. the German Eichrecht law). Ability to exchange live data can enable services such as smart charging.
- **Billing**
  Should be depending on connection time and/or energy charged and on the contract with company EV user subscribes to. Furthermore, the billing functionality should be able to deal with international differences, e.g. concerning taxation. Alternatively, the charging session can be paid for via ad hoc local payments.
- **Data security and privacy**
  Given the highly privacy sensitive information of charging sessions data, the protocol should ensure secure data exchange and protect the privacy of the users

4.2 Architectural openness

We suggest architectural openness to be a design principle for roaming protocols. This can be described as the degree in which a protocol can easily cater for the integration of new elements. This can be achieved with a modular design, in which the protocol consists of several independent modules that each support a specific functionality. In such a design, modules can be added, updated or removed from the protocol without affecting the development and performance of the other modules in the protocol. Architectural openness is important in order to accommodate innovations, or to respond to changing environmental conditions (such as the introduction of new regulations such as GDPR). For instance, if a protocol currently only defines NFC as a form of authentication, can authentication by the charging plug (ISO 15118) be easily added? A standard that defines a list of authentication options, and thus allows an authentication option to be added by putting it on that list without even having to update the standard, is an example of a standard with a high degree of architectural openness. Architectural openness can also by achieved through a modular design.

4.3 Use of options

Another design principle can be to allow protocol users to implement 'options'.[6] Including options is related to architectural openness in that a protocol can be adapted to the specific needs of a protocol user, but it differs in that architectural openness means that new functionalities and data fields can easily be included in the protocol, while with options protocol users can (to a degree) choose which ones to implement and/or use and add new options for their specific needs. This is important because we expect new parties, new business models, and new services in e-mobility in the coming years. New options are likely to be necessary to enable new, unforeseen functionalities. On the other hand, these options may not be necessary for or not desired by every stakeholder involved in charging infrastructure. A protocol that includes specific options allows stakeholders to use it in a way that best serves their needs. Important is, however, that if an implementer decides to use an option in a device in service, that it has to do so precisely how the protocol defines that option, to ensure interoperability between those that chose for these options.

4.4 Scalability

We suggest the protocol should be scalable in terms of performance. With this we mean, for instance, that the processing capacity needed to enable data exchange should scale linearly with the number of data exchange requests. This is key to ensure that roaming can function also with the expected growth in e-mobility.

4.5 Quality control

We identified three dimensions for which we recommend some form of quality control and support of quality control: (1) conformance with other standards, (2) support to assess the quality of implementation, and (3) support to assess the quality of data input. Below, we elaborate on each of these.

[6] Other commonly used words for options in standards are profiling and modules (note that we use the concept modular differently as a way to achieve architectural openness)

4.5.1 Conformance with other standards

Ensuring conformance with other standards is necessary to achieve interoperability with other roaming protocols in use and sub-systems of charging infrastructure, e-mobility, and the electricity grid for which other standards are used. Ensuring conformance requires cooperation and coordination amongst related standardization bodies and testing tools for new protocol updates.

4.5.2 Support to assess the quality of implementation

A standard or protocol usually describes certain functional, behavioural or performance aspects, but usually does not specify how these should be implemented (in hardware or in software).[7] The actual implementation is usually left to the party that adopts (implements) the standard. So, in practice, one might find many independent implementations of a given standard. Such different protocol implementations may boost competition and innovation but may also lead to errors or difficulties in connecting parties. Even if those that wrote the standard thought that they defined everything in a very tight, complete and "waterproof way", it may be so that different implementers, that later read that text, actually understand different things out of the text. Even when all had best intentions, they may have ended up creating different implementations that do not to work together (i.e. are not interoperable). Ensuring interoperability between implementations is a major concern among all types of (interoperability) standards.

In the context of EV roaming, several interviewees indeed stated that some parties have implemented protocols differently because of different interpretations of certain elements of the protocol. Standard developers can help with ensuring quality of implementation in the following manners:

- Systematically collect feedback on possible ambiguities in the standards' text and improve that in new versions
- Provide reference implementations of the standard (e.g. software code that implementers can chose to use, or that implementers can use to test interworking with their own implementations)
- Offer certification or interoperability services, or support the development of such services by others.[8]
- Offer certification or interoperability tools, which implementers can use to test proper implementation (e.g. software or hardware tools), or support the development of such tools by others.[9]

[7] An exception would be when a standard also includes a binding implementation, such as a software code. In-between cases are where a reference implementation is provided, for the convenience of implementers, but where parties are free to create their own implementations as well if they wish so (for whatever reason: performance, costs, better integration in their own product, etc.).

[8] An example here is the WiFi Alliance, which provides certifications that devices implement the IEEE 802.11 series of Wireless LAN Standards in a certain way that they are interoperable.

[9] An interesting example here can be found in the late 1980s, when the first European digital mobile telephone standards was developed, GSM. At that time, because of the great importance of testing terminals, operators from France, Germany, Italy, and the UK granted a single contract to Rohde & Schwartz from Germany for standard testing equipment, to be used in all GSM testing houses in Europe [25]. Because of the great importance of testing terminals, operators from France, Germany, Italy, and the UK granted a single contract to Rohde & Schwartz from Germany for standard testing equipment, to be used in all GSM testing houses in Europe.

- Organize events or activities where implementers of the standard can test the interoperability of their implementations in practice, and check whether they behave in the expected way when plugged together with implementations of other parties (hence the name “plugfests”).

4.5.3 Support to assess the quality of data input

We recommend some form of quality control on data exchange, especially regarding charge point location and technical specifications. Several interviewees stated that one of the major issues in the current roaming system is lacking or faulty information regarding charge point location and technical specifications. Though this issue cannot be completely solved by protocol developers, they could try to implement some form of quality control on data exchange, for example by clearly describing the required format of data input in a manual, and having error messages appear when parties provide incomplete data or data not adhering to the required format.

4.6 Open standard (WTO TBT definition)

In order to allow a large variety of stakeholders to be involved in the standardization process, among other things, we recommend the protocol to be governed as an open standard. What constitutes open standards is part of an ongoing discussion, see [58]–[62]. In response to the discussion on open standards, the World Trade Organization’s Committee on Technical Barriers to Trade (WTO TBT) formulated the following six principles for international standardisation processes: The principles are (1) transparency, (2) openness, (3) impartiality and consensus, (4) effectiveness and relevance, (5) coherence, and (6) address the concerns of developing countries [22]. A truly open standard according to these principles can (ideally) incorporate market demands in a democratic and transparent way, improves the fit of the protocol in the regulatory landscape, and can give the protocol a competitive advantage. Below, we elaborate on each principle.

4.6.1 Transparency

The principle of transparency stipulates that “all essential information regarding current work programmes, as well as on proposals for standards, guides and recommendations under consideration and on the final results should be made easily accessible to at least all interested parties in the territories of at least all WTO Members” [22]. Furthermore, there should be procedures established for parties to provide written comments, which should allow for adequate time and opportunities to do so, and for these comments to be taken into account in further consideration of the standard. The WTO TBT further specifies that the group developing the standard should publish a notice of new developments at “an early appropriate stage” when amendments can still be introduced and comments taken into account, and communicate this to members of the standardization body through established mechanisms. The standard has to be published when adopted, and the developers should periodically publish a work programme containing information on the standards currently being prepared and adopted.

While the WTO TBT recognizes the Internet to be a useful means of ensuring timely provision of information, it also states that there should be procedures in place to enable provision of hard copies of information documents.

4.6.2 Openness

The principle of openness stipulates that "membership of an international standardizing body should be open on a non-discriminatory basis to relevant bodies of at least all WTO Members".[22] This openness should hold for participation at the policy development level and every stage of the standards development, such as the proposal and acceptance of new work items, the technical discussion on proposals, the submission of comments on drafts in order that they can be taken into account, reviewing existing standards, voting and adoption of standards, and dissemination of the adopted standards. Every member of the standardizing with an interest in the specific standardization activity should be able to meaningfully participate at all stages of the standard development.

4.6.3 Impartiality and consensus

The principle of impartiality and consensus stipulates that "all relevant bodies of WTO Members should be provided with meaningful opportunities to contribute to the elaboration of an international standard so that the standard development process will not give privilege to, or favour the interests of, a particular supplier/s, country/ies or region/s" [22]. The WTO TBT emphasizes that standards development should be consensus based, and procedures should be established that seek to "take into account the views of all parties concerned and to reconcile any conflicting arguments." This principle should be accorded throughout the standards development process, including, among other things, access to participation in work, submission of comments on drafts, consideration of views expressed and comments made, decision-making through consensus, obtaining of information and documents, dissemination of the international standard, fees charged for documents, right to transpose the international standard into a regional or national standard, and revision of the international standard.

4.6.4 Effectiveness and relevance

The principle of effectiveness and relevance stipulates that standards need to be effectively responding and relevant to regulatory and market needs, and scientific and technological developments. Newly developed standards "should not distort the global market, have adverse effects on fair competition, or stifle innovation and technological development", and "should not give preference to the characteristics or requirements of specific countries or regions when different needs or interests exist in other countries or regions" [22]. In order to achieve this, there should be procedures in place to identify and review standards that have become obsolete, inappropriate, or ineffective, and procedures that aim to improve communication with the WTO.

4.6.5 Coherence
The principle of coherence stipulates that international standardization bodies should "avoid duplication of, or overlap with, the work of other international standardizing bodies" [22]. To achieve this, cooperation and coordination amongst related standardization bodies is needed.

4.6.6 Development dimension
The development dimension means that "tangible ways of facilitating developing countries participation in international standards development should be sought" [22]. Developing countries typically have more constraints to effectively participate in standards development, and these should be taken into consideration in designing the standards development process, in order to ensure that developing countries are not excluded de facto from it.

4.7 Business model agnostic
Related to our discussion of open standards, our final recommendation is to have a business model agnostic protocol. This means that the protocols are flexible enough to support any desired business model for roaming. Most relevant in this regard for roaming protocols is that they can support both peer-to-peer connections and roaming platform connections.

5. Current roaming protocols compared to design principles for an 'ideal' roaming protocol

This chapter compares the current roaming protocols OCHP,[10] OICP,[11] eMIP,[12] and OCPI[13] with the proposed design principles for an 'ideal' roaming protocol we presented in the previous chapter. We base our comparison mainly on analyses of the protocol documentations [1]–[6], and extend this with results from our interviews. This chapter discusses the technical characteristics and governance of the protocols only briefly, for a more detailed overview we refer to Deliverable D6.1 Comparative analysis of roaming protocols (see Section 1.3). Table 1 presents an overview of our evaluation.

5.1 Inclusion of core functionalities

We evaluate the inclusion of core functionalities as follows:

- **Identification of EV users**
  Identification of EV users is possible in each of the roaming protocols under review. OCHP supports identification by RFID card, remote identification, and ISO 15118. OICP supports identification by RFID card, QR code, plug-and-charge, and remote identification. eMIP supports identification by means of definition tables, and new modes of identifications can be integrated without needing a standard update. OCPI supports identification via apps, RFID cards, and other means. OCHP, eMIP and OCPI use tokens for identification. We evaluate his criterion as high for all protocols.
- **Authorization of charging sessions**
  OICP, eMIP, and OCPI support authorization both via whitelists (offline) as well as real-time authorization (online). We evaluate his criterion as high for these protocols. OCHP currently only supports offline authorization, but in the next update live authorization should be supported as well. Therefore, we evaluate his criterion as high/medium for OCHP.
- **Recording charging session information**
  All protocols support recording of charging session information, but these is a difference in the degree to which they enable live exchange of charging session information. OCHP and OICP do support live data exchange on charge point status, but not for charging session information. This is planned to be included in future updates of OCHP; therefore, we evaluate his criterion as high/medium for OCHP. To our knowledge, there are no plans to include this in OICP in the near future, which is why we evaluate this criterion as medium for OICP. eMIP offers a message service, enabling CPOs to report events to MSPs and MSPs to request actions of COPs during a charging session. We evaluate, this criterion as high/medium for eMIP. OICP fully supports live data exchange of charging sessions information. We evaluate his criterion as high for OCPI.

[10] OCHP version 1.4 and OCHPDirect version 0.2

[11] OICP version 2.2

[12] eMIP version 0.7.4

[13] OICP version 2.2

- **Billing**
  All protocols support billing, using CDRs as the basis for invoicing.
  We evaluate his criterion as high for all protocols.
- **Data security and privacy**
  All protocols support data exchange via secured HTTPS-based transport layers only. OCHP and OCPI use token-based anonymization, and OICP uses encrypted hash values for authentication data. The eMIP documentation specifies that MSPs might anonymize contract IDs. It is beyond the scope of this study to state whether these measures are enough to be GDPR-compliant.

5.2 Architectural openness

eMIP is considered a protocol with a high degree of architectural openness. For instance, when it comes to authentication, it defines a list of authentication options, and thus allows an authentication option to be added by putting it on that list without even having to update the standard. OCPI defines, next to the categories 'RFID' and 'app', a category 'other' for identification, also providing a high degree of flexibility. We thus evaluate this criterion as high for eMIP and OCPI. The OCHP and OICP protocols do not allow to add new authentication methods without having to change the standard, which is why we evaluate this criterion as low for these protocols.

5.3 Use of options

OCPI is explicitly set up as a protocol that offers a range of options[14] that users are free to implement or not, which is why we evaluate it as high for this criterion. OCHP does not offer options in the standard as such, but does have the optional extension OCHPDirect, which is why we evaluate it as medium for this criterion. OICP offers a limited set of options (messages for reservation, requests for charge point information, and requests to stop the charging). Therefore, we evaluate the protocol as medium for this criterion. eMIP does not offer optional functionalities (only optional data fields), which is why we evaluate it as low for this criterion.

5.4 Scalability

Assessing the scalability of the protocols is outside the scope of this study, as this is hard to assess based purely on protocol documentation and interviews.

5.5 Quality control

There should be some form of quality control on several dimensions. We have identified the following: (1) conformance with other standards, (2) quality of implementation, and (3) quality of data input. Below, we elaborate on each of these.

[14] Named modules in the protocol documentation.

- **Conformance with other standards**
  The developers of all these protocols are working together in projects to realize interoperable protocols. Furthermore, they are actively seeking for input in protocol development from adjacent sectors. As stated above, the e-mobility field is still developing, and so are the adjacent sectors of transport and energy. Roaming standards are being developed next to other standards (e.g. for plug-and-charge and smart grids) that ideally these are interoperable with. While this will be a work-in-progress for the foreseeable future, there are thus efforts to realize this conformance. We evaluate this criterion as high/medium for all protocols.
- **Support to assess the quality of implementation**
  For OICP and eMIP offer extensive protocol descriptions, certification, and implementation tests when parties want to connect to the associated roaming platforms. We therefore evaluate this criterion as high for these protocols. OCHP also offers an extensive protocol description and an implementation test for connecting to e-clearing.net. We evaluate this criterion as high/medium for OCHP. For OCPI there is protocol documentation available, but no implementation tests. Furthermore, several interviewees mentioned that different implementations of OCPI have led to errors in connection. We evaluate this criterion as medium for OCPI.
- **Support to assess the quality of data input**
  All protocol documentations give description of the data fields, which are detailed enough that they should lead to correct data input. Therefore, we evaluate this criterion as high for all protocols. However, that several interviewees told us that in practice there are a lot of issues with the quality of the data input. While beyond the responsibility of the standard developers, roaming platforms could perhaps play a role in promoting correct data input amongst connected parties.

5.6 Open standard

We discuss the degree to which the roaming protocols adhere to the WTO TBT criteria for open international standardization [22] in great detail in Deliverable D6.1 Comparative analysis of roaming protocols (see Section 1.3). Table 1 presents an overview of our evaluation.

	OCHP	OICP	eMIP	OCPI
Core functionalities				
Identification of EV users	+	+	+	+
Authorization of charging sessions	+/0	+	+	+
Recording charging session information	+/0	0	+/0	+
Billing	+	+	+	+
Data protection	*	*	*	*
Architectural openness	-	-	+	+
Use of options	0	0	-	+
Scalability	*	*	*	*
Quality control				
Conformance with other standards	+/0	+/0	+/0	+/0
Support to assess quality of implementation	+/0	+	+	0
Support to assess quality of data input	+	+	+	+
Open standard				
Transparency	+	+	0	+
Openness	0	0	-	Current: +/0 Future: +
Impartiality and consensus	0	-	-	+/0
Effectiveness and relevance	+	+	+	+
Coherence	+	+	+	+
Development dimension	0	0/-	0/-	0
Business model agnostic	+	0	0	+

*Table 1. Our evaluation on how the protocols score on our proposed design principles. + indicates high, 0 indicates medium, - indicates low, * indicates that it is out of scope of this report to assess this aspect. For details, see Deliverable D6.1.*

5.7 Business model agnostic

OCHP and OCPI support both peer-2-peer and hub connections, so we evaluate them as high for this criterion. OICP and eMIP support only roaming hub connections, and the protocol documentations of explicitly mention as the roaming platform Hubject and GIREVE respectively [3]–[5]. However, in our interview round it was stated that both protocols are free to use by anybody as they wish, so it could also be used to connect to other roaming platforms or peer-to-peer. Therefore, we evaluate these protocols as medium on this criterion.

6. Summary and recommendations

This report presents design principles for an 'ideal' EV roaming protocol. To do so, we first discussed perspectives on the future of roaming as found amongst a diverse set of stakeholders and desk research. This investigation shows that the demand for roaming (including cross-border roaming) is expected to increase, new business models and services are expected to arise, regulation is expected to play an increasingly important role in the development of public charging infrastructure and roaming, and e-mobility is expected to be integrated in new transport business models and technologies, and smart energy systems. Furthermore, many interviewees characterized e-mobility as not mature and still developing.

Based on these perspectives, we conclude that there is a high need to achieve seamless (cross-border) roaming, but there is also a need for a flexible protocol that is able to incorporate new, unforeseen protocol functionalities. To accommodate both needs, we propose that an 'ideal' should be based on the following seven design principles: (1) inclusion of core functionalities, (2) architectural openness, (3) use of options, (4) scalability, (5) quality control, (6) open standard, and (7) business model agnostic.

We then compared the functionalities and governance of the current major roaming protocols in Europe (OCHP, OICP, eMIP, and OCPI) with these design principles. The comparison shows that several of the design principles can be recognized in the protocols. For example, the protocols have included all of our proposed core functionalities in some form. We see more divergence between the protocols on the design principles architectural openness and use of options. Assessing the scalability of the protocols is outside the scope of this study.

The protocols score very similar on two of the three dimensions of quality control (conformance with other standards, support to assess quality of data input), All protocol development teams make efforts to be interoperable with other relevant protocols. This will remain important for the coming years, as many of the other relevant protocols are also still developing (e.g. for smart charging and vehicle-to-grid). In our view, the protocol documentations provide enough information to help CPOs and MSPs with providing quality input data. However, practice shows that in practice there is still a lot of lacking and faulty data in the roaming system. We recommend roaming hubs and aggregators to develop other measures to check the quality of input data. There is more divergence for support to assess quality of implementation. All roaming hubs provide implementation tests, Hubject and GIREVE also provide certification, but for OCPI this is not yet available. We would like to point out options to assess the quality of implementation beyond what the protocol developers already offer: (1) implementation tools available to anyone could help parties correctly implement protocols without having to connect to a roaming hub, and (2) organize activities or events (sometimes called "Plugfests") to allow parties to test the interoperability of their protocol implementations in practice.

We can also see divergence between the degrees to which protocol governance adheres to the principles of open standards as formulated by the WTO TBT [22]. The difference between the protocols is especially relevant for the dimensions openness and impartiality and consensus, where OCHP and OCPI score higher than OICP and eMIP. Furthermore, we would like to draw attention to the medium and medium/low scores for the development dimension. While there are discussions about roaming protocols in IEC working groups, developing countries are not involved. The same holds for the project for which this research was carried out (evRoaming4EU), which focussed only on European stakeholders. Acknowledging the challenges of studying the future of charging infrastructure in countries with small EV fleets, we recommend further research to make an effort to include perspectives from developing countries.

The final design principle we discussed is business model agnostic, by which we mean that the protocols are flexible enough to support any desired business model for roaming. Most relevant for roaming is whether they support peer-2-peer connections and roaming platform connections. OCHP and OICP explicitly support both type of connections, while OICP and eMIP are designed only for roaming platform connections.

While our proposed design principles are strong in the sense that we expect many stakeholders to see the logic they are based on and, on a general level, support them, the interpretations and translations of these to specific protocol functionalities and governance can differ amongst development teams. Ideally, protocol developers share best practices of realizing not only open charging infrastructure but also open, robust, and flexible protocols.

Appendix A. Interview protocol

1. Roaming protocol development

Currently, there are several roaming protocols in use. We would like to discuss:

a. Your organizations' use of roaming protocols
b. Your awareness of the different roaming protocols
c. The technical and functional differences between the roaming protocols
d. Progress and challenges roaming protocol development
e. The role of regulation in roaming protocol development and innovation

2. Your current business model and support of existing charging protocols

We would like to discuss your organizations' business model and position in the value chain of EV charging. Here, we discuss charging protocols in the broad sense (i.e. not limited to roaming protocols). We would like to discuss:

a. Your business model and position in the value chain
b. How charging protocols you currently use support, but also hinder your business model

3. The future of your business model

E-mobility is relatively new and the field is developing rapidly. We would like to discuss:

a. The future business model of your organisation
b. New activities in the value chain
c. What functionalities charging protocols should have to facilitate these activities

4. Your view on the future of the public EV charging infrastructure

Related to the previous point, we would like to discuss your view on the future of the public EV charging infrastructure. We would like to discuss:

a. Trends in public EV charging infrastructure
b. Number of parties active in EV charging infrastructure in the future (many versus few firms with monopolistic tendencies)
c. Role of traditional automotive firms versus the role of new players and firms from sectors such as energy and ICT

5. Pathways to harmonization

There are several scenarios for achieving full roaming functionality between all public charge points worldwide. We can think of a scenario in which existing roaming protocols merge in one single standard and a scenario in which gateway technologies are used to achieve interoperability. Gateway technologies are systems that interface with two or more different protocols to the best degree possible. We would like to discuss:

a. Importance of achieving interoperability
b. Likeliness of both scenarios
c. Whether another scenario is likely

d. Advantages and disadvantages of the scenarios
e. Main lessons from sectors such as telecommunication, the Internet and banking in achieving a standard for roaming
f. Applying these lessons to e-mobility

6. Involvement in roaming protocol development

Currently several efforts are undertaken to set up organizations for the development and management of roaming protocols. We can also imagine a future in which such responsibilities are transferred to large standard setting organisations such as ISO, IEC, IEEE, or CEN/CENELEC. We would like to discuss:

a. Desirability of such efforts
b. Your interest in being involved in further developing these protocols and in what manner

Appendix B. List of interviewees

Table 8. List of interviewees. Eight interviewees participated under the condition of anonymity and are not presented in the list.

Interviewee	Organisation	Country
Michel Bayings	eMobility consulting	Netherlands
Gilles Bernard	AFIREV	France
Alfred Böhm	Stromquelle Energietechnik GmbH	Austria
Nuno Maria Bonneville	MOBI-E	Portugal
Diego García Carvajal	European Copper Institute	Spain
Onno Ceelen	EVBox	Netherlands
André Martins Dias	CEIIA	Portugal
Moritz Dickehage	Smartlab GmbH	Germany
Lonneke Driessen	ElaadNL	Netherlands
Roland Ferwerda	NKL	Netherlands
Christian Hahn	Hubject	Germany
Doris Holler-Bruckner	Austrian Sustainable Mobility Association	Austria
Daniel Kulin	Power Circle	Sweden
Kor Meelker	Allego	Netherlands
Freerik Meeuwes	EVBox	Netherlands
Anas Munir	Smartlab GmbH	Germany
Eric Munneke	Eco-movement	Netherlands
Fredrik Nordin	Bee Charging Solutions	Sweden
Christian Peter	Electro-Mobility Club	Austria
Arne Richters	Allego	Netherlands
Stephan Riechel	ENBW	Germany
Jean-Marc Rives	GIREVE	France
Maxime Roux	Freshmile	France
Ernesto Ruge	Giro-e	Germany
Martijn Santbergen	Vattenfall	Netherlands
Tobias Schneider	Innogy	Germany
Dietrich Sümmermann	Share and Charge	Germany
Kai Weber	Bosch	Germany
Ewoud Werkman	TNO	Netherlands
Kristian Winge	Sycada	Netherlands

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