9

Communication with and for Electric Vehicles

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1. Introduction

While electric vehicles (EV) are already widespread in particular applications, e.g. fork lifts or baggage carrying (cf. Rand et al., 1998), their use as individual motor cars is still limited. E.g., only 2,300 EV were registered in Germany on 1st of January 2011 (Federal Motor Transport Authority, 2011). However, many drivers lead towards an electrification of individual motor car traffic all over the world: advancing battery technology, high oil prices in 2008 and 2011, the recent automobile crisis in 2009 and the hope for ecological advantages of EV usage.

Moreover, the combination of two major energy conversion systems, namely the electric utility system and the light vehicle fleet (e.g. individual motor cars), could create considerable synergies (Kempton & Letendre, 1997; Kempton & Tomic, 2005a; Tomic & Kempton, 2007). One proposed concept is Vehicle-to-Grid realized through "... vehicles with an electric drive motor powered by batteries, a fuel cell or a hybrid drive train, [that] can generate or store electricity when parked, and with appropriate connections can feed power to the grid …" (Kempton & Tomic, 2005b).

EV can be subdivided into hybrid EV (HEV) and battery EV (BEV). The subset of HEV combines the (parallel or serial) electric drive motor with a combustion engine, a fuel cell or human power (e.g. Pedelec). The BEV rely only on a – mainly electro-chemical – energy storage. Although the energy to fulfill an HEV's mobility function could be provided alternatively (e.g. by fuel or a battery exchange), all EV are assumed to be plug-in vehicles in this article. This means they charge from and possibly discharge into the power grid. All in all, the term EV refers from now on to (at least partly) electrically propelled cars used for individual motor traffic which can be conductively or inductively connected to the power grid.

A lot of research questions have been raised with respect to EV. Most of them approach the subject from a technical (e.g. battery performance), economic (e.g. total cost of ownership) or a user (e.g. driving behaviour) perspective, others investigate social, political and cultural barriers for broader EV usage (Sovacool & Hirsh, 2009). Information and communication technology (ICT) (definition cf. Krcmar 2006), is affected in all of these perspectives, since it has to …

- be mastered technically,
- be used economically, and
- increase usability.

Moreover, research questions can be categorized with respect to an EV's life cycle which on a top view corresponds to the serial phases of production, usage and recycling. While questions about production aim at producing EV efficiently for the market demand, the

recycling phase refers to economic and ecologic EV elimination. In the usage phase, questions about the EV in interaction with users and infrastructure are to be answered.
The usage phase will be in focus during the following considerations.The remainder of this chapter is structured as follows. At first, the closer consideration of the fixed and intersection point of energy transmission is motivated (section 2). Afterwards, fundamental dimensions for use cases around the energy transmission are presented and discussed (section 3). The informational dimension is further detailed to an information system in a separate section (section 4). Subsequently, the example of e-mobility roaming illustrates why and how the top view of such an information system is necessary (section 5). Finally, concluding remarks summarize the status quo and give an outlook on future research (section 6).

2. Fixed and intersection point: energy transmission

The usage of EV brings a major problem into focus: energy. Likewise conventional vehicles, comfortable and safe mobility can only be guaranteed by a sufficient amount of energy available in an EV at every point in time. Thereby, "sufficient" depends on the efficiency of the EV as well as the circumstances of its use. While a small city car can be very efficient and rarely requires energy for more than 100 km per day, a SUV of a traveling salesman is rather energy consuming and could need energy for 1000 km or more.
Three fundamental ways of energy transmission are currently discussed for EV: conductive charging, inductive charging and battery exchange. For one EV, a combination of these general transmission types is possible, for example normally recharging conductively at home, but exchanging a battery to realize a rare long trip to visit relatives. Though, such a combination of different energy transmission technologies clearly comes along with higher costs.
Due to high costs and a low energy density of its storage, especially BEV still have the disadvantage of a low energy storage capacity (cf. Figure 1, left). Neglecting the technically more complex battery exchange as well as inductive charging when driving, lifetime considerations of the (most often) electro-chemical storage requires slow charging and leads to a rather time-consuming replenishment. In contrast to these disadvantages in comparison with conventional vehicles, BEV profit from the fact that electricity is already quasi-omnipresent allowing for many potential suppliers. Conventional vehicles and (to a certain extent) fuel-based HEV rely on petrol stations operated by only a few companies at well distributed, but at a limited number of places (compare Figure 1, right).

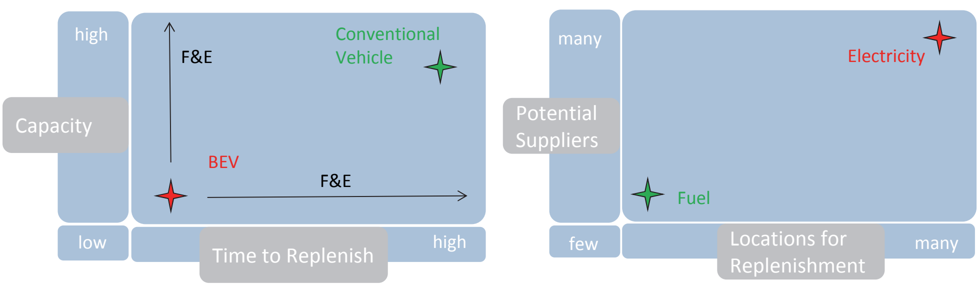


Fig. 1. Qualitative comparison of energy storage and availability between BEV and conventional vehicles

To sum up, the discussion at this point reveals that although BEV are unprivileged with respect to the energy storage, the potential availability of energy is significantly higher. Therefore, the energy transmission between BEV and the power grid is an important factor of all BEV applications. Although HEV are not fully reliant on the power grid, the idea of sustainable mobility by charging renewable energy is realizable only for the charged energy. Henceforth, all EV business models are forced to define how and when the EV are to be served with energy. This is why the energy transmission between the power grid and an EV can be seen as a fixed point of EV usage (cf. Fig. 2), in case of BEV a particular important one.

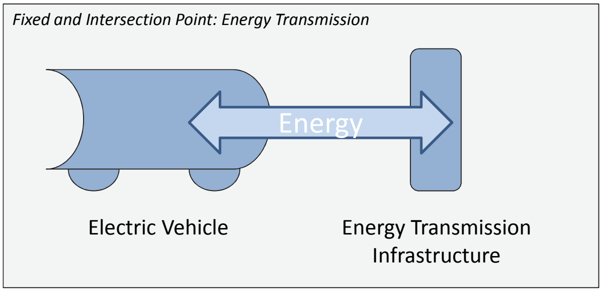


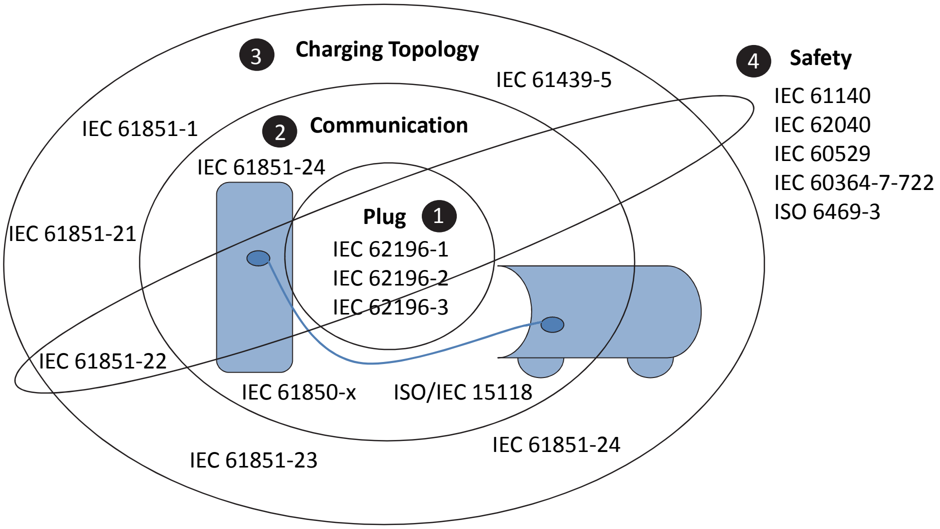
Fig. 2. Fixed and intersection point of EV business models

The energy transmission is not only a fixed point of EV usage, but also a point of intersection of different EV business models. For example, an EV manufacturer could assume the EV buyer to normally charge via a standard power outlet at a standard parking place (e.g. at home). However, mobility of EV implies that the EV could be anywhere else other than this standard parking place when the battery runs out of energy. Henceforth, the EV manufacturer needs to offer the possibility for energy transmission at other than the standard parking places. The same applies for a car sharing or a car rental company as well as taxi or delivery services. In all of these examples, an EV can get energy at the standard parking place most of the time, but occasionally, the EV would rely on foreign energy transmission infrastructure. Consequently, energy transmission is at the same time a fixed as well as intersection point of EV usage.

For conventional vehicles, this point of intersection clearly is the petrol station. Independent of the exact vehicle usage, a conventional vehicle can be refueled through the standardized filler necks. The petrol stations are not available everywhere, but they are well distributed over high frequented places. However, this concept works well only for vehicles with a huge energy storage capacity as well as a fast refueling process. Henceforth, it is improper for all the EV that need to charge regularly, but can not store huge amounts of energy.

3. Fundamental dimensions for energy transmission use cases

By recognizing the energy transmission as a fixed as well as intersection point of business models, it becomes apparent that isolated infrastructure is inefficient and renders all business models unprofitable. Therefore, significant efforts are necessary to standardize the energy transmission – best on an international level to keep production costs low and allow for e-mobility roaming (cf. chapter 5). This standardization is currently undergoing in several working groups of the ISO and IEC in cooperation with national institutes. Fig. 3 gives an overview of standards that exist or are currently developed for conductive charging of EV. With respect to communication between charging infrastructure and EV, the standards ISO/IEC 15118 (protocol stack for Powerline Communication), IEC 61850-x (adaption of substation protocols for EV) and IEC 61851-24 (direct current charging) are particularly relevant.



IEC 62196-1: Plugs, socket-outlets, vehicle couplers and vehicle inlets Conductive charging of electric vehicles, Charging of electric vehicles up to 250 A a.c. and 400 A d.c.
IEC 62196-2: Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles, Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories
IEC 62196-3: Plugs, socket-outlets, and vehicle couplers - conductive charging of electric vehicles, Dimensional interchangeability requirements for pin and contact-tube coupler with rated operating voltage up to 1 000 V d.c. and rated current up to 400 A for dedicated d.c. charging
IEC 61850-x: Communication networks and systems in substations
ISO/IEC 15118: Vehicle to grid communication interface
IEC 61439-5: Low-voltage switchgear and controlgear assemblies, Assemblies for power distribution in public networks
IEC 61851-1: Electric vehicle conductive charging system – General requirements
IEC 61851-21: Electric vehicle conductive charging system – Electric vehicle requirements for conductive connection to an a.c./d.c. supply
IEC 61851-22: Electric vehicle conductive charging system – a.c. electric vehicle charging station
IEC 61851-23: Electric vehicle conductive charging system – D.C electric vehicle charging station
IEC 61851-24: Electric vehicle conductive charging system – Control communication protocol between off-board d.c. charger and electric vehicle
IEC 61140: Protection against electric shock - Common aspects for installation and equipment
IEC 62040: Uninterruptible power systems (UPS)
IEC 60529: Degrees of protection provided by enclosures (IP Code)
IEC 60364-7-722: Low voltage electrical installations, Requirements for special installations or locations - Supply of Electric vehicle
ISO 6469-3: Electrically propelled road vehicles, Safety specification, Protection of persons against electric shock

Fig. 3. Standards for conductive charging of EV (German National Platform for E-Mobility, 2010)

The fixed point of energy transmission can be characterized and designed with respect to various dimensions. Three fundamental dimensions shall be distinguished in the following:

- Electrical (e.g. charger or specification of plug)
- Organizational (e.g. parking place type or infrastructure owner)
- Informational (e.g. ICT hardware or authentication protocols)

The electrical dimension is the core of energy transmission. That is why international standardization efforts have focused on this dimension for a long time. Though, organizational and informational aspects become more and more important. Organizational questions appear with respect to relevant roles and business models (cf. Fig. 4). Informational aspects are to be investigated since ICT is a promising enabler for EV usage due to several reasons:

1. Process efficiency for energy supplier and infrastructure operator could be increased.
2. Consumer protection laws require instant, reliable and verifiable information about transferred energy quantity and corresponding prices for the EV user.
3. The possibility to offer value added services such as the routing to and the reservation of functioning and free places at the energy transmission infrastructure.
4. More sophisticated concepts such as Vehicle-to-Grid rely on sophisticated real-time information.

Role	Example(s)	Organizational Question(s)
User	• Social services • Delivery services	Where, when and how should one's EV be charged? How to ensure that the EV are always charged adequately?
Vehicle Provider	• Car sharing company • Car rental company	How to ensure that customers are able to charge where ever needed in a comfortable manner?
Mobility Provider	• Taxi	What is the charging status of each EV and which EV is therefore should take which customer?
Energy Provider	• Energy supplier • Distribution network operator	How can a customer be provided with energy in transit? How is it possible to avoid overcharge a certain grid string when lots of EV are charging?
Parking Area Operator	• Supermarket • Visitor parking area	How to best comfort customers by providing energy for EV?

Fig. 4. Organizational questions of energy transmission to EV

One could regard the informational dimension linking the electrical and organizational aspects in order to harmonize the process before, during and after the energy transmission.

The organizational dimension does not need to include the commercial (financial, contractual, etc.) aspects, in contrast to the business level identified elsewhere (Bolczek, 2010). Instead, it can be assumed that basic organizational aspects are describable without assuming certain roles or business models. For example, procedures to access infrastructure have to be consistent throughout roles and business models and therefore need to be described independently.

There are abstract use cases that can be characterized around the fixed and intersection point of energy transmission throughout the three fundamental dimensions. The use cases themselves can be part of one or several business models.

In each dimension, a number of attributes can be identified while an attribute can be instantiated by one or several values. This can be seen as a simple morphological box (cf. Zwicky & Wilson, 1967). The combination of values over attributes and dimensions leads to a particular use case. Many and manifold use cases are possible, however, only a few particular types will fit to the requirements of business models in the long run. An excerpt of such a box is given in Fig. 5.

Dimension	Attribute	Value(s)					
Electrical	Energy Transmission	Conductive		Inductive		Battery Exchange	
	Plug Specification	CEE 7/7	CEE 3P+ N+PE, 6h	JARI Level 3 DC	IEC 62196-2	SAE J1772	SCAME
	...	...			...		
Organizational	Entitled to dispose of infrastructure	Natural Person (private: individual)		Legal Person (private: company)		Legal Person (public: authority)	
	Access Level	EV parking place		EV supply equipment		Electricity	
	...	...		...		...	
Informational	Top Level Elements	User		EV	EV Supply Equipment	IT-Backend	
	Authentication Hardware	RFID		SmartCard		Mobile Phone (SimCard)	
	...	...		...		...	

Fig. 5. Excerpt of attributes in the morphological box in three dimensions

With respect to the communication with and for EV, the informational dimension is pertinent and will be focused on in the following.

4. Information system for electric vehicles

The informational dimension can be described via an information system. An information system is a social and technical system that combines human and mechanical components to achieve the optimal allocation of information and communication (cf. Heinrich, 2005; Krcmar, 2007). The description of such an information system is the base to design an adequate information flow within and throughout the manifold business models. As seen before, the point of energy transmission is a fixed point for all EV. Henceforth, this fixed point is a useful starting point for the description of an information system for EV usage. Top level elements of such an information system are elements that play a prominent role when it comes to using or processing information. Those elements were identified to be the user of the EV, the EV itself, the point of energy transmission, as well as the supporting IT-Backend (cf. Fig. 6). Deliberately, the IT-Backend resembles a cloud, since – with some ups and downs – there is a continuous trend towards the flexible utilisation of IT-Infrastructure and services over (high speed) internet connections.

An information system can be detailed via an information system architecture. Several information system architectures have been proposed (The Open Group Architecture Framework, 2010; Scheer, 2000; Krcmar 2007). However, on the top level the architecture components are very similar and the architectures differ mainly with respect to their illustration. Although, the information system architecture concepts were originally developed for enterprises to describe and design their information system, it can be adapted to fit the needs for an information system around EV usage.

According to Krcmar (2007), an information system architecture consists of six components, namely

- Infrastructure

- Communication architecture
- Data architecture
- Application architecture
- Organizational architecture
- Strategy

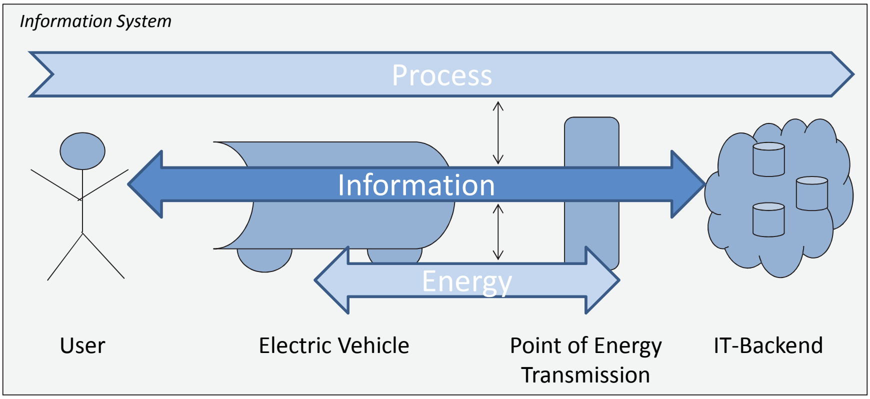


Fig. 6. Top level elements of the information system for EV

The components are structured hierarchically, from rather physical ones (infrastructure) to rather logical ones (strategy). In order to emphasize that these components must be well balanced to achieve efficient information flows, Krcmar used the spinner to illustrate the relations of the components (cf. Fig. 7).

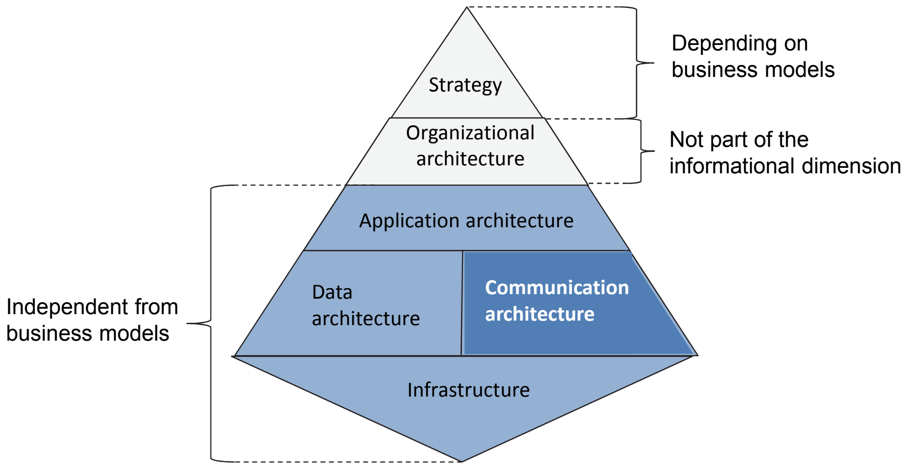


Fig. 7. Information system architecture as spinner (adapted from: Krcmar, 2006)

The architecture originally was designed for enterprises which realize at least one business model. Thus, the creation of use case types independent of business models requires an adaption of the general architecture. At first, due to the close relation to long term profit, the strategy has to be left out. Secondly, the organizational architecture that stands for a company's process and structural organization is not part of the information dimension (cf. section 3). Well adapted for a base for use case types are the infrastructure, the data architecture, the communication architecture as well as the application architecture. They can be characterized as follows:

- The infrastructure contains all design elements of ICT hardware, for example which kind of microcontroller, CPU, graphics card, etc. are used.
- The data architecture consists of data models and objects that are necessary to provide information to EV users and other stakeholders.
- The communication architecture describes the topology for communication as well as the used protocols.
- The application architecture is built up on the first three components in order to provide defined functions for users and systems.

However, these components of an information system can hardly be interpreted in an isolated manner, but are in close relation and interaction. Thus, despite the focus on the communication architecture, the remainder of this chapter will also contain aspects of infrastructure, data and functions.

With respect to the communication with and for EV, it is useful to adapt the general information system overview (Fig. 6) and explicitly model the most important IT-Systems (Fig. 8). In addition to the EV, a mobile device as well as a fixed device is available for an EV user. A device shall be considered "mobile" in this context when an EV user can handle it comfortably in an upright position. For the following examples, the abstract level of energy transmission is left and conductive charging is assumed:

- An example for a mobile device is a mobile phone that can be used to unlock a charging station via a hotline call or a SMS. Alternatively, the widespread smartphones are able to unlock the charging station via an application ("App") offered by the energy supplier of the EV user.
- An example for a fixed device is a desktop personal computer or a notebook. Via a client application or a website, they allow for an offline check of the individual charging behaviour (e.g. place, energy and cost).

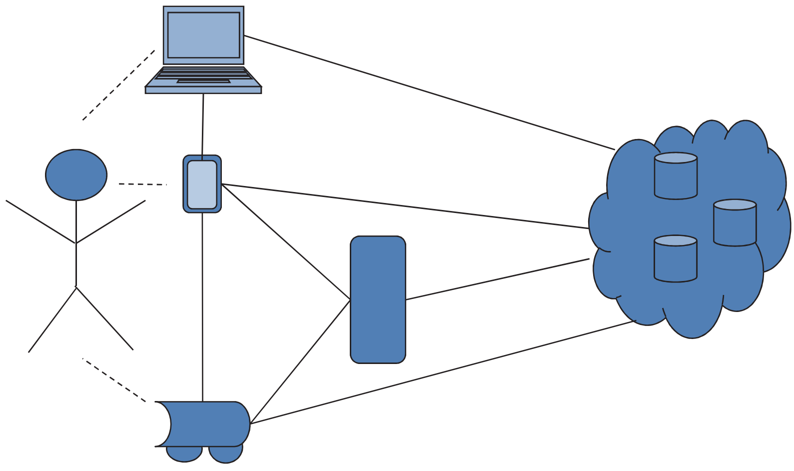


Fig. 8. Communication architecture from an EV user perspective

This adapted view of the information system is the infrastructural base of communication from the EV user perspective. In this chapter, the server landscape in the IT-Backend is not further detailed. Although, design and operation of applications and services in the IT-Backend is challenging, the questions that are to be asked and answered are not necessarily specific for e-mobility. In many cases, the integration of e-mobility in existing software solutions is the core problem. This is done via interfaces of which four already appear in the chosen illustration (Fig. 8).

After this introduction to the information system at the fixed point of energy transmission to and from an EV, an example shall illustrate how this information system view can help to master the current informational challenges of EV usage. Interesting examples would be:

1. Access to own infrastructure under consideration of authentication, authorisation and accounting.
2. Access to foreign infrastructure under consideration of authentication, authorization and accounting.
3. Collection and transmission of metering data with respect to the conflicting goals of usage transparency, data reliability and data privacy.
4. Value added user services such as routing to or reservation of infrastructure.
5. Vehicle-to-Grid services such as frequency regulation.

Since Vehicle-to-Grid services and value added user services are not solving one core problem of e-mobility (“enough energy for mobility”), they might be less interesting at this point. For a discussion of the collection and transmission of metering data, the different national laws play an important role. However, access to infrastructure is a prior subject in all countries, and when using foreign infrastructure an informational interesting one. Therefore, the following chapters use this subject, later defined more precisely as e-mobility roaming, to illustrate the information system in detail. For the sake of convenience, again the conductive charging is assumed. For inductive charging or battery exchange, similar considerations can be made.

5. E-mobility and roaming

5.1 Motivation

Considering private car owners, they can be distinguished by the type of their standard parking place (e.g. at home). Either car owners have a dedicated parking space such as a garage, or they park curbside somewhere nearby. The former can charge the EV by simply plugging it into a fixed socket-outlet in their garage. In this case, no identification and authorization is needed – however possibly useful in the future for providing grid services (Vehicle-to-Grid). While charging at the standard parking space can cover most trips, recharging is necessary from time to time if the trip distance is higher than a typical EV-range or recharging at the standard parking space is not possible. Hence, in such cases, these EV owners rely on foreign charging infrastructure for which physical access, authentication, authorization and accounting (AAAA) is needed. The latter group, i.e. EV owners parking curbside, need foreign charging infrastructure every day.

Carsharing companies can have dedicated parking spaces for their cars. For EV usage, they can upgrade them with electric vehicle supply equipment (EVSE). Thus, whenever an EV is parked there, it can be recharged by using individual methods for AAAA. Since many carsharing offers still restrict the start and end of any rental to these dedicated parking spaces, regular recharging is guaranteed. However, for two reasons this is not enough: First of all, in some cases, the user might need to additionally recharge somewhere else. Secondly, the product "carsharing" mainly sells easy access to individual mobility. Therefore, the most successful carsharing companies will allow the start and end of a rental anywhere which endangers regular recharging at the dedicated parking spaces. A carsharing company can enable recharging not only at those own dedicated parking spaces, but also at foreign charging infrastructure by guaranteeing AAAA there.

Term	Definition
E-Mobility Provider	Contracts with EV Users in order to offer services (e.g. charging) and can be EVSE Operator at the same time.
EV User	Uses an EV within a contract with an E-Mobility Provider.
EVSE Operator	Operates at least one EVSE as a service for E-Mobility Providers, but has no continuous contractual relation to EV Users.

Fig. 9. Terms to define e-mobility roaming

All in all, these two simple and known business models already show that the usage of foreign charging infrastructure would occur regularly. This is often referred to as e-mobility roaming, in analogy to the mobile communications sector. More precisely, roaming with cellular phones means the uninterrupted availability of all services while moving out of range of the former carrier to another one (Schiller, 2003). On this base as well as with the definitions in Fig. 9, e-mobility roaming (or just roaming) in this paper refers to the situation in which an EV User is using an EVSE within a contract with an E-Mobility Provider that is not the EVSE Operator of the used EVSE (cf. Fig. 10).

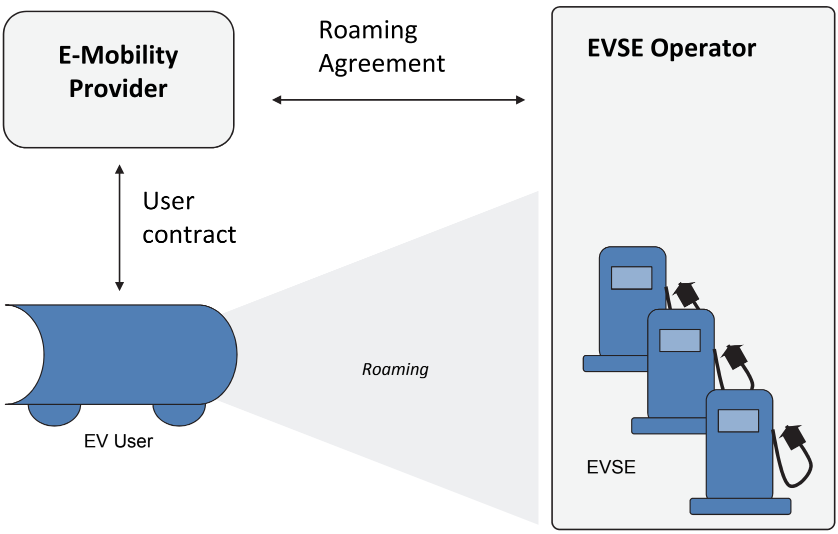


Fig. 10. E-mobility roaming

Due to the still prevailing regional and local character of many power markets (e.g. in Germany), roaming is likely to happen not only international, but even within one town or street. Having a contract with every single provider is very uncomfortable. Hence, mechanisms to enable AAAA for roaming are inevitable. In order to guarantee a user-friendly e-mobility roaming experience, there are several challenges to cope with. Paying cash or via credit card is uncomfortable and requires more expensive infrastructure than identifying as a user through an adequate contract.

5.2 Challenges of roaming

On the base of the above understanding of e-mobility roaming and its business context, a closer look is taken at the preconditions of roaming. Since roaming involves two or more parties, the preconditions are closely related to questions of interoperability and the use of standards. Preconditions of roaming can be grouped into electrical and commercial issues, each concerning aspects of the underlying medium or its use (Fig. 11).

	electrical	commercial
medium	I	III
use of medium	II	IV

Fig. 11. Categories of requirements for roaming in e-mobility infrastructure

For example, a straight forward requirement for an electrical medium (I) is – assuming conductive charging – a standardized EV plug. Since the usage of adapters is very uncomfortable, an EV plug should fit into the outlet of all EVSE. The International Electrotechnical Commission (IEC) therefore currently revises the international standard IEC 62196. Considering other ways of getting power into an EV, such as induction or battery exchange, different requirements must be fulfilled. For inductive charging, a consistent form and position of the charger and the inductor is vital. For the battery exchange, especially the size and interface of the batteries as well as the security concept must be compatible. Beyond pure physical characteristics of the underlying medium, there is a need for its standardized use (II). For example, successful conductive charging requires voltage, current, frequency and charge mode to be correctly adjusted on both sides as well as to the cable diameter. These basic parameters can be negotiated via a control pilot signal as defined in SAE J1772.

From a commercial point of view, the charging of an EV requires a medium for containing or conducting data for authentication, authorization and accounting (AAA) (III). Authentication of a user in front of an EVSE could be done for instance via RFID cards, magnetic or smart cards, key panels or near field communication by cellular phones. Alternatively, authentication data can be transferred via a communication line directly out of the EV. In order to exchange the commercially relevant data, the use of the media must be further specified by standards for protocols and data types (IV). Considering protocol aspects, the standard IEC 15118 is currently developed. It will enable the automatic exchange of information between an EV and an EVSE. Therefore, standard message types for transferring session, status, metering and billing data are defined on different layers of the OSI Model. In addition to protocols using the communication connection, there is a clear commercial need for the definition of basic identifiers (IDs) that can be used throughout the information systems of involved companies. The remainder of this paper focuses on identification issues and discusses possible and necessary IDs for roaming with EV.

5.3 Identifiers for roaming

Every Identifier (ID) has a certain scope in which it is valid. For roaming, the distinction of intra-company and inter-company IDs (henceforth called uniform IDs) is essential. While intra-company IDs such as customer numbers are sufficient for many commercial applications, roaming requires uniform IDs for involved objects to allow for inter-company data exchange. Since uniform IDs require significant standardization efforts, it is worth to investigate which IDs should to be uniform in which cases. The cases clearly depend on the underlying business model(s) and technical choices. However, two abstract scenarios can cover many of them. Both scenarios differ from each other only with respect to the sequence of communication steps (Fig. 12).

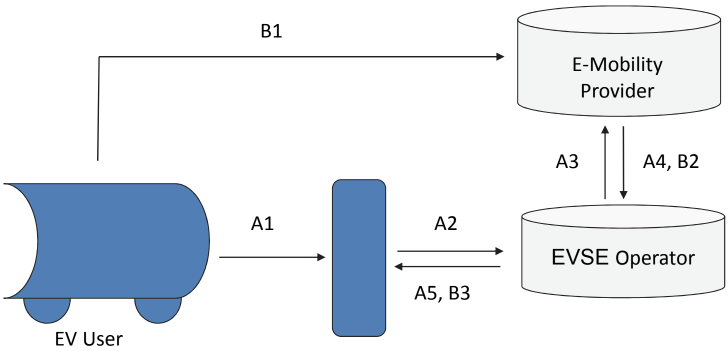


Fig. 12. Two scenarios for the sequence of communication steps

In scenario A, the EV User (or its EV on behalf of him) passes all information needed for authentication through the EVSE (A1) to the EVSE Operator (A2). The EVSE Operator forwards the information to the E-Mobility Provider and requests AAA for the EV User (A3). If the response (A4) is positive, the EVSE Operator unlocks the EVSE for charging (A5). In scenario B, the EV User directly connects to the E-Mobility Provider (B1) for AAA. If authorization is successful, the E-Mobility Provider requests the EVSE Operator (B2) to unlock the particular EVSE for charging (B3).

Identifiers	Scenario A	Scenario B
E-Mobility Provider	Required *operator need to know which provider to contact*	Optional *provider known by operator*
EV User	Optional *user known by provider*	Optional *user known by provider*
EVSE	Optional *EVSE known by operator*	Optional *EVSE known by operator*
EVSE Operator	Optional *operator known by provider*	Required *provider need to know which operator to contact*

Fig. 13. Requirement of uniformity depending on scenario

Investigating four roaming relevant IDs reveals that – with respect to the need for uniformity – each scenario requires at least one uniform ID (Fig. 13). However, even where uniform IDs are optional, standardization of such IDs is advantageous. Assuming scenario B with authentication of an EV user by a cellular phone, the EV user needs to transfer the IDs of the EVSE and the EVSE Operator to the E-Mobility provider. If the EV User is required to manually type these numbers in his cellular phone, the usability decreases considerably when all EVSE Operators use very different formats for these IDs. Very comfortable would be an App that allows to take a picture of a code (e.g. bar code, matrix code, or simply number in standardized format) in order to get the EVSE ID on the smartphone.

6. Conclusion

At the beginning of this chapter, it was motivated why the energy transmission to EV is of high relevance. Its character of a fixed and intersection point was explained. For this fixed and intersection point, three fundamental dimensions, namely the electrical, the organizational and the informational dimension, were presented and discussed. Afterwards, the informational dimension was further detailed with the help of an information system. The relevance and usage of the information system finally was illustrated by the example of e-mobility roaming.

All in all, with EV being at the point of broader market penetration, the question of the informational integration of these EV into infrastructure and its interaction with user services becomes more important. Although, information and communication technology has to be seen as a helpful enabling technology of EV usage, it has to be stated that ICT itself needs resources to efficiently serve the requirements of EV stakeholders.

Even though many activities have already started (cf. standardization), a lot of more effort is needed to efficiently and economically use ICT for EV. The proposed overview of an information system that explicitly combines the user perspective with ICT components at an adequate chosen fixed and intersection point (“energy transmission”) can be a good starting point for the integration of on-going research activities and derivation of further research questions.

7. Acknowledgment

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8. References

Bolczek, M. (2010). Business Models for Electric Vehicles. *Proceedings of the 2nd European Conference on Smart Grids and E-Mobility,* p. 34, ISBN 978-394185144. Brussels, Belgium, October 20-21, 2010

Federal Motor Transport Authority (2011). *Emissionen, Kraftstoffe - Deutschland und seineLänder am 1. Januar 2011*. 17.3.2011. Available from http://www.kba.de/cln_015/nn_269000/DE/Statistik/Fahrzeuge/Bestand/EmissionenKraftstoffe/2011__b__emi__eckdaten__absolut.html

German National Platform for E-Mobility, NPE (2010). *The German Standardization Roadmap – E-Mobility Version 1*. Figure 12, p. 28. 30.11.2010. Available from:

http://www.elektromobilitaet.din.de/sixcms_upload/media/3310/Normung-Roadmap_Elektromobilit%E4t.pdf

Heinrich, L.J. & Lehner, F. (2005). *Informationsmanagement.* Oldenbourg.ISBN 978-3486577723, München, Germany

Kempton, W. & Letendre, S (1997). Electric vehicles as a new power source for electric utilities, In: *Transportation Research Part D – Transport and Environment 2 (3)*, Elsevier Science Ltd., pp. 157-175, Great Britain

Kempton, W & Tomic, J. (2005a). Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy, In: *Journal of Power Sources 144 (1)*, Elsevier Science Ltd., pp. 280-294, Great Britain

Krcmar, H. (2006). Information Management, Springer, ISBN 978-3540206286, Berlin, Germany

Kempton, W & Tomic, J. (2005b). Vehicle-to-grid power fundamentals: Calculating capacity and net revenue, In: *Journal of Power Sources 144 (1)*, Elsevier Science Ltd., pp. 268-279, Great Britain

Rand, D.; Woods, R. & Dell, R. (1998). *Batteries for electric vehicles*, Research Studies Press Ltd., John Wiley and Sons Inc., ISBN 978-0863802058, N.E. Bagshaw

Scheer, A.-W. (2000). *ARIS - Business Process Modeling*, Springer, ISBN 978-3540658351, Berlin, Germany

Schiller, J. (2003). *Mobile Communications*, Addison Wesley, ISBN 978-0321123817, p.113, München, Germany

Sovacool, B. & Hirsh, R. (2009). Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition, In: *Energy Policy 37 (3)*, Elsevier Science Ltd., pp. 1095-1103, Great Britain

The Open Group (2009). The Open Group Architecture Framework - TOGAF Version 9. Van Haren Publishing, ISBN 978-9087532307, Great Britain

Tomic, J. & Kempton, W. (2007). Using fleets of electric-drive vehicles for grid support, In: *Journal of Power Sources 168 (2)*, Elsevier Science Ltd, pp. 459-468, Great Britain

Zwicky, F. (1967). The morphological approach to discovery, invention, research and construction, pp. 273-297 In: *New Methods of Thought and Procedure. Contributions to the Symposium on Methodologies*, May 22-24, 1967, Pasadena. Springer-Verlag, New York. 17.3.2011. Available from:
http://www.swemorph.com/pdf/new-methods.pdf