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Energy Procedia 136 (2017) 157–162

Energy Procedia

www.elsevier.com/locate/procedia

4th International Conference on Energy and Environment Research, ICEER 2017, 17-20 July 2017, Porto, Portugal

Inter-service provider charging protocol: a solution to address range anxiety of electric vehicle owners

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Abstract

Range anxiety describes the drivers' stress regarding the available battery range while driving an electric vehicle. Considering this issue as a barrier against general acceptance of electric vehicles, several researches has been reviewed. The results show that there is no direct communication among current networks of charging stations which causes isolation in these networks. Thus, the users are not able to use cross-network facilities which leads to range anxiety. To overcome, a protocol is suggested to be used in development of RESTful web services to provide direct communication among the networks of charging stations.

Peer-review under responsibility of the scientific committee of the 4th International Conference on Energy and Environment Research.

Keywords: Charging infrastructure; charging networks; communication protocols; electric vehicle; range anxiety

1. Introduction

In electric vehicles (EV) industry, charging infrastructure (CI) plays a significant role. Availability of CI is an important factor in general acceptance of EVs and lack or insufficient number of charging stations will cause range anxiety [1–7]. Range anxiety is the term to describe drivers' concern about remaining power while driving an EV.

Considering the range anxiety as a barrier against success of EV industry, and to highlight the importance of mitigating this issue, a systematic literature review has been conducted on it. Research and review papers focusing on EV and range anxiety published between 2008 and 2016 were extracted from IEEE Explore, Science Direct, Society of Automotive Engineers (SAE) International, and Association for Computing Machinery (ACM), with the combination of "Electric Vehicle" and "Range Anxiety" as keywords. The review results are presented in section 2.

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1876-6102
Peer-review under responsibility of the scientific committee of the 4th International Conference on Energy and Environment Research.
10.1016/j.egypro.2017.10.313

By focusing on CI, the second objective of the paper is to introduce a protocol to provide direct communication between EV service providers (SP) and to provide cross-network charging. Thus, in sections 3 networks of charging stations are reviewed. In section 4, a communication protocol is presented to provide a unified communication between SPs of EV charging networks. The paper is summarized with a conclusion in section 5.

2. Range anxiety

Range anxiety is a known issue in EV industry referring to the fear of the EV owner to be left on the road with an empty battery before arriving the destination. Since 1997, when the term was brought up for the first time, several studies have been performed on this issue. Unavailability of CI on users' demand, long charging time, shorter driving range comparing to internal combustion engines, and initial price of an EV are among factors which discourage society to widely accept EVs as a primary transportation. Although with recent improvements in EV industry the driving range is increasing, and DC fast chargers can charge an EV up to 80% in 30 minutes (or less), still the charging time and range of EVs are not comparable to the range and refueling time of an internal combustion vehicle.

One of the major issues highlighted by researchers is lack or insufficient number of public charging stations. Although the charging process mostly happens during the night at home or in parking lots during the day, availability of public charging stations is an important factor in reducing range anxiety. Therefore, deployment of widely distributed networks of charging stations will provide flexibility in planning long trips. However, the long charging time in compared to internal combustion vehicles is still an issue. Thus, providing fast charging facilities which will charge an EV up to 80% in 30 minutes (compare to 6-8 hours while slow charging) will address this issue [8–17]. However, user access to these charging stations is also another matter, which is discussed in section 3.

On the other hand, some researchers suggest to provide battery swapping stations in which the depleted battery can be changed with a full one in as much time as required for filling the tank in conventional vehicles. Therefore, deployment of battery swapping stations is required. Optimally located stations, size and capacity of the station, availability of full batteries on EVs' arrival, and exhaust level of batteries are important factors which needs to be considered in design of such networks [18–21].

Besides public battery charging/swapping stations, charge-while-drive using electrified roadways and wireless power transfer is also highlighted as another solution by some researchers. Since the user does not need to worry about the recharging process, it has a significant impact on user's range anxiety and provides ease of use for them.

3. Network of charging stations

A group of EV users registered under the same SP to use charging equipment are considered as a network. In a network of EVs, the satisfaction level of the users relies on the availability of the service when it is required, cost, and timing of getting the service. On the other hand, the location and distribution of a charging station is a major factor to benefit consumers and SPs. An appropriate located charging station can bring user convenience and assure the benefits of the SP. Currently there are different SPs which service their registered users and use several ways to identify and authenticate them; the most popular one is using RFIDs. Normally, before starting the charging process, the user needs to be identified and when the charging finished, billing and payment information will be sent to them. Therefore because of SPs' closed networks, the possibility of being in a place far away from the registered network for users will increase.

A brief investigation on current EV networks, charger manufacturers, and charging infrastructure providers (based on their commercial websites) was conducted to verify their authentication mechanism, and communication methods between EVs and their Charge Points (CP), CP and their Central System (CS), their CS and other networks' CSs. It is concluded that the primary authentication mechanism is using RFIDs. However, some networks are providing alternative authentications such as mobile applications or SMS services.

Open Charge Point Protocol (OCPP) is the ideal and most popular communication protocol between CP and CS, which is supported by most of CPs and it is being used by most of SPs. Yet, some charger manufacturers also provide customized interfaces for this purpose as well. SAE J1772 (Type 1), Type 2 and CHAdeMO are main charging types. Some Charger manufacturers and networks are providing combo charging systems as well. It is expected that most of DC fast charging CPs being equipped with combo connectors.

The investigation also proves lack of a universal communication between EV networks. However, third party companies such as EZ Charge in North America and Hubject in Europe are trying to fill this gap by covering several networks under one contract and providing shared charging facilities among networks, yet these facilities are only available for participating networks.

Besides availability of CI, which is considered as an important factor in general acceptance of EVs, the possibility of having access to use them is also important. Since current networks of charging stations only service their registered users, the possibility of being in a place where there are charging stations, but not the ones in which the driver has registered will increase.

To overcome the access issue, EV users can subscribe to several EV networks and carry multiple authentication devices; which is not convenient and practical. Therefore, SPs can join third-party interface companies (such as Charge Your Car, Hubject, EZ Charge, etc.) and these companies will provide inter-network authentication for EV users. But the problem is not solved yet. The subscription is still required and from user-level moved to SP-level. Once there are several interface companies, the SPs need to subscribe to more than one of them (and of course pay the subscription fees). Another option is to use direct payment with credit cards. Although it looks convenient and easy method to let EV users to charge their cars, but the purpose of subscription into charging networks, besides having access to charging facilities, is to gather historical data about electricity consumption by each EV for further planning of smart charging and smart grids. Therefore, in this research we are introducing a communication protocol to bring networks of EVs together.

4. Inter-Service Provider Charging Protocol (ISPCP)

Since the charging process starts with authentication of the EV user, the focus of this protocol is to link the authentication devices to the right CS of any SP. As depicted in Fig. 1, ISPCP is an interface protocol to standardize the communication among SPs. Currently most SPs are using OCPP as the communication protocol between the CP and CS. Since ISPCP is only focused on the communication between SPs, to use this protocol a customization need to be applied on authorization mechanism of OCPP which is explained in the next section.

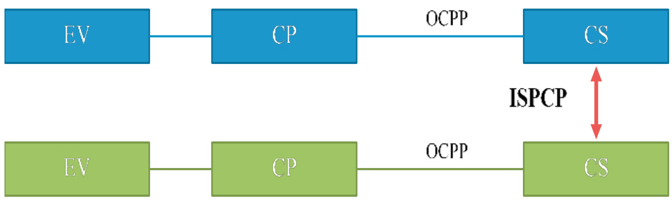

Fig. 1. ISPCP as an interface between two SPs.

4.1. OCCP authorization

In OCPP the CP will send a AuthorizeRequest message to the CS for requesting authorization. In OCPP 2.0 the message contains a idTag field which its type is IdToekn. IdToekn is a class with two properties: Id, and IdType. IdType is an enumeration specifying the type of identification with the following values: ISO14443, ISO14443Reversed, EMAID, EVCCID, EVCOID, ISO7812, CardTxNbr, Central1, Central2, Local1, Local2, and PhoneNumber. If IdType is not specified, RFID UID is assumed as ID [22].

To use ISPCP with RFID, a new IdType needs to be defined named “Service”. If the IdType is service, the id that CP is sending to CS is a JSON string containing a service URL. CS will use that URL to identify the SP and get authorization details.

4.2. *ISPCP details*

The charging process starts by EV user sending charge request to the CP. The CP sends the authorization information to its own CS. The CS verifies the user and if the user is not an internal user, it uses the authentication details to verify the external CS. The external CS receives the user's detail and if the user is authenticated, the proper authorization acknowledgment will be sent back to the charging CS. Then the CS will send notification to the CP and the charging process will start.

The communication between different CSs are standardized in ISPCP. This protocol will be used during development of a Representational State Transfer (RESTful) web service. REST is a method of providing interoperability between systems over the Internet. Fig. 2 depicts the authorization process for an external user.

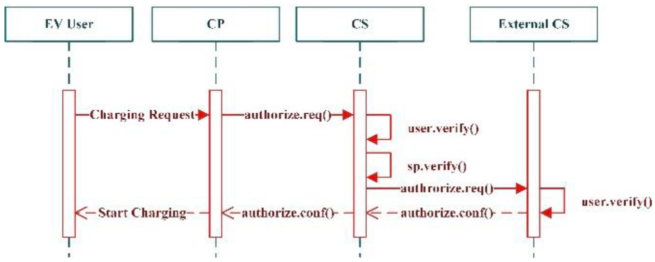

Fig. 2. Authorization process sequence diagram.

4.2.1. Authorization devices

To be able to identify users, SPs provide different authorization methods to their subscribed users. Prior to charging, the user needs to be authorized. Since ISPCP needs more details about the user and its SP, there needs to be more information on the authorization devices.

- RFID: While there are two approaches for using RFID tags (data-on-tag and data-on-network), to use ISPCP, the combination of these two approaches needs to be used. Therefore, authentication and gateway information will be stored in user memory bank of RFID, while details of the users and servers are stored in servers.
- Mobile Application: Some SPs provide mobile apps which let the user to get verified using the app and a barcode displayed on the CP. The user scans the barcode and the app handles the authorization process.
- Barcode: ISPCP proposes a new authentication mechanism to store users' data as barcodes. The CP needs to be equipped with a barcode scanner and the users only need to scan their barcode prior to charging.

The data for any of the authentication mechanisms needs to be stored in a standards way. Below is the sample of data format:

{"svr":"serice address", "id": "user/CP Id", "sp":"sevice provider", "inf": "extra info"}

4.2.2. Authorization

Based on the authorization method, the process may be initiated from CP or CS. If the authorization method is barcode or RFID, the CP will send the authentication details to CS. In this method, the authorization steps are as follows:

1. CP scans user's RFID or barcode
2. CP sends authentication information to CS
3. CS verifies the information. If the request is from an external user and if the external CS is identified, the request will be sent to external CS
4. External CS verifies the user and responses the request
5. CS sends authorization confirmation message to CP
6. CP releases the plug and charging will start

If the user is using mobile application to get authorized the CS will verify the user and send unlock command to CP. The authorization steps are as follows:

1. User scans the barcode on the CP
2. Mobile application sends the CP information to CS.
3. CS verifies the information. If the CP is an external CP and if the related CS is identified, the request will be sent to external CS
4. External CS verifies the request and if the CP is identified, authorization confirmation message will be sent to CS
5. CP releases the plug and the charging will start

4.2.3. ISPCP Messages

ISPCP is a protocol to standardize the messages communicated between SPs. The important transactions which needs to be handled by ISPCP includes authorization, billing, and payment. All the messages in ISPCP is sent using POST HTTP verb with JSON (application/json) body. The messages are:

- *authorize-req*: to verify a user
- *bill-req*: to get the billing details
- *payment-req*: to ask for payment
- *payment-res*: to send payment details

When an external user requests for charging with RFID card, barcode, or mobile application, the user's detail and their own SP's information are included in their authorization device. The SP that receives the request will use the user's SP information to communicate with it. Below is an example of the *authorize-req* message:

```
POST authorize-req HTTP/1.1
Host: https://api.ispcp.com
Content-Type: application/json
{
 "reqid":"8aa791d6-fcf7-4cbc-a96b-b8f4442d2343",
 "userid":"3abddb90-377c-4e28-b1d2-7acc9d48c586",
 "sp": {
  "srv":"https://api.3rd-party-example.com/",
  "name": "My Comany Name", ...
 }
}
```

5. Conclusion

As an important issue in EV industry, range anxiety needs to be lessened. Researchers show that availability of charging infrastructure is an important factor in relieving range anxiety. In this paper, we highlighted that beside availability of charging stations, users need to have access to them. After reviewing existing charging networks, it is confirmed that there is no direct communication between these networks, therefore the users are not able to use facilities of the networks other than the one in which they have registered. Thus, availability of charging facilities is not enough to address range anxiety issue. Therefore, we proposed a communication protocol to be used in development of service interfaces among EV SPs and let them directly communicate with each other. Applying this protocol on new and existing networks will provide cross-network charging facilities to users by only subscribing to one network. Since during the trip, users do not need to worry about whether they can use a charging station on their destination or not, their range anxiety will be relieved.

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