One Plug at a Time – Designing a Peer-to-Peer Sharing Service for Charging Electric Vehicles

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Abstract. The widespread diffusion of electric vehicles (EVs) suffers from the lack of a well-developed public charging infrastructure, which currently is uneconomical to develop for investors. Many owners of EVs have private charging stations at their premises, which yield unlockable potential due to high idling times. In line with sharing platforms for other goods like accommodations and cars, we present the design, prototypical implementation, and evaluation setting of *CrowdStrom*, a peer-to-peer sharing service for charging EVs that networks individuals, their charging stations, and charging service customers.

Keywords: Electric Vehicle, Charging Infrastructure, Peer-to-Peer, Sharing, Design Science Research

1 Infrastructures for Electric Vehicle Charging

Clean, carbon-neutral transportation, fueled by electricity generated from renewable sources has been on governments' agendas for years. Central to these ambitious development plans is the potentially widespread diffusion of electric vehicles (EVs) [1]. While the German government, which is pursuing a target of one million registered EVs in Germany by 2020 [2], provides financial incentives for EV-buyers, registrations remain low with little more than 50,000 EVs registered by the end of 2015 [2]. In a circular pattern, customer adoption of EVs has been hampered by the lack of a well-developed public charging infrastructure [1], and the resulting limited demand for EVs deters investors from developing these infrastructures. Many owners of EVs have private charging stations at their premises, which yield unlockable potential due to high idling times. Peer-to-Peer (P2P) sharing has been proposed as way to increase the availability and use of existing resources by granting public access to individually owned resources [3]. P2P sharing facilitates IT-enabled economic transactions between individuals, where only temporary access to a physical resource is granted by a resource owner to others who need it in exchange for a monetary consideration [4]. The shift in

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consumer attitude from preferring ownership of a resource to preferring access to it has fueled the rise of IT-enabled P2P sharing services in domains such as transportation (e.g. *BlaBlaCar*) and accommodation (e.g. *Airbnb*) [3]. The central component of such services is a Web platform that brings together peer-providers and peer-consumers and that provides a framework for handling business transactions [5].

Against this background, we adopt the P2P sharing paradigm to enable individuals and businesses to share their private charging stations with other EV-drivers.

The remainder of the paper is structured as follows: section two sketches the research approach and the activities conducted in the course of the CrowdStrom project. Section three introduces the business model and the CrowdStrom platform, while the fourth section closes with the discussion of a comprehensive evaluation setting.

2 Research Approach

We adopt the Design Science Research (DSR) paradigm [6] to develop a business model and an instantiation of a P2P service for sharing EV-charging stations within a joint industry-and-academia consortium. In line with research guidelines on DSR [6], our work follows the cyclic process of the DSR Methodology (Figure 1).

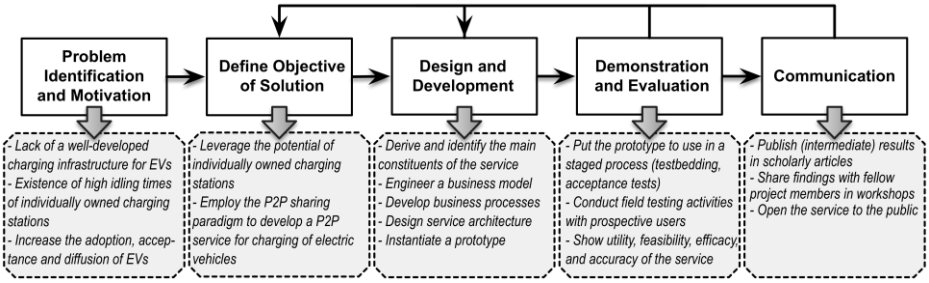

Figure 1. Overview of the DSR phases adopted for the CrowdStrom project

After identifying the mentioned societal problem, we further developed and communicated the project's objectives in multiple design cycles [7]. During the design and development phase, we addressed different issues of the EV-charging challenge ranging from customer-related (acceptance, willingness-to-pay), provider-related (incentives, organizational development), and legal aspects (energy provision, taxation) to service design (procedural/ technical design principles) [4]. We will subsequently conduct a comprehensive evaluation to advance the prototype into a mature solution.

3 The CrowdStrom Business Model and Prototype

The CrowdStrom service networks individuals and businesses that provide charging stations (peer-providers), and EV-drivers that require charging (peer-customers). Additionally, a service operator acts as intermediary that runs the central Web platform, handles transactions, and provides support services in return for a share of the revenue. The roles of the peer-provider and peer-customer are not mutually exclusive, i.e., users

may both provide charging stations and use the ones of other users. Peer-providers connect their charging stations to the platform and define hourly prices according to location and power output. While the service is not intended to generate large revenue for peer-providers, it reduces the total cost of ownership of their already existing and individually bought charging stations. Furthermore, we identified a strong solidarity within EV-drivers and societal aspects to positive influence peers to become providers [7]. Peer-customers register at the service and then use the Web platform to search for and possibly reserve charging stations nearby. Additional filters for distance, price, charge rates [kW/h], plug types, green power, and customer ratings may also be applied to the search process. Peer-customers authenticate themselves at the charging station by means of RFID cards, text messages or the Web front-end. Charging sessions are recorded and fed back to the platform, so both providers and customers can have dashboards that transparently reflect their service usage (charging sessions, total energy transferred, current balance, invoices) and to facilitate an automated billing process that settles balances monthly.

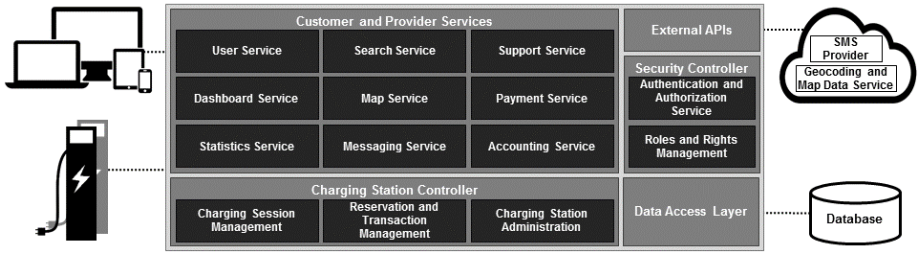

Figure 2. CrowdStrom Platform Components and Services Architecture

Figure 2 depicts the implemented solution design of the prototypical CrowdStrom platform. We leverage state-of-the-art open-source technologies (e.g. *AngularJS*, *Materialize*) for the responsive Web front-end and the server back-end (e.g. *Java EE*, *MySQL*). The charging station controller handles communication between charging stations and the platform, using the de facto standard *OCPP*. We rely on third-party providers for geocoding, cartographic material, and SMS handling. A central security service manages user authentication and authorization based on privileges and roles. Depending on the user's role, a range of functions and services is offered.

4 Evaluation and Outlook

VENABLE et al. define four evaluation strategies for DSR projects [8], from which we selected the *Human Risk & Effectiveness* strategy, as it focusses on socio-technical aspects of the service and on its real-world application. In earlier design cycles, we iteratively improved CrowdStrom's business model, processes, and service delivery mechanisms by conducting artificial formative evaluations in form of expert interviews, simulated experiments, and workshops with domain experts and technicians from our partnering local utility. For the final evaluation, we will conduct a naturalistic summative evaluation [8] in which we rigorously evaluate the validity and effectiveness of the

prototype and its underlying design to ensure their utility in the real-world environment they were designed for. We will conduct two field tests for which we invite potential users to become peer-providers or peer-customers to gain insights regarding both roles.

For the first field test, we provide participants with a charging station to set up at their premises and connect to CrowdStrom in order to experience being a peer-provider for one day. During the course of the test, project members will mimic customers and perform charging sessions. Afterwards, we conduct semi-structured interviews with the participants to understand their experiences regarding the setup process, functionalities of the prototype, financial prospects, and interaction with test customers.

For the second field test, we scheduled 30 participants to perform a one-hour long test drive in an EV that entails comprehensive use of the CrowdStrom platform, i.e., search for a charging station, reserve it, visit it, and conduct a charging session. To assess the perceived ease-of-use of the solution, participants will answer semi-structured interviews. In addition, their interaction with the prototype will be screen-captured and monitored. Since both field tests will be very resource intensive (fleet of EVs, charging stations, personnel) the number of participants, especially on the provider side, will be rather small. Nevertheless, by closely monitoring and surveying the participants, we are sure to receive fruitful evaluation results that will help to improve CrowdStrom, reduce uncertainties about social and use issues, validate the ability of the design to solve the initially identified problems, and inform the launch of the platform.

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