Parking Lot Management for Charging Stations

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Abstract: During the last years electric vehicles started to gain significant attention from customers and car manufacturers. As the number of electric vehicles on the road increases, new requirements emerge to update existing charging station infrastructures. In this paper we address the issue of management of parking lots where charging stations are deployed since existing parking management systems do not consider charging stations and charging station management systems are not able to manage parking spaces. We propose a solution in which a charging station uses sensors to detect whether the assigned charging spaces are occupied; monitors customer's interaction with itself and forces to take actions within the given period of time. If there is a violation of terms of use, our solution enables to inform the management system in order to take the necessary steps. Furthermore, it provides visual guidance to customers in search for parking space and during the interaction.

1 INTRODUCTION

In recent years, there has been a growing interest in electric vehicles due to concerns about climate change, greenhouse gas emissions and fossil fuel prices. With technological innovations in battery and power management many car manufacturers embrace producing electric vehicles. Despite the fact that more charging stations are deployed every year in parking lots, their numbers are still limited. As a result the more efficient use of parking spaces where public charging stations are deployed becomes invaluable: These parking spaces should only be occupied by authorized electric vehicles. Yet existing parking management systems and solutions only address the availability of free parking spaces.

In this paper we propose a solution that can be employed in existing charging stations. The concept involves the use of sensors in order to determine whether a vehicle is parking or not, monitoring customer interaction with the charging station while introducing time-based restrictions and warning him/her accordingly. If the warning is ignored and therefore the use of the charging station violated, we provide a mechanism to inform a central system about the situation. Moreover, this management system is coupled with a guidance system that proposes the use of luminaries with three basic colors. In the following we differentiate between the terms *parking lot* and *parking space*. A parking space is a location for parking of one vehicle. A parking lot is a dedicated area for parking of multiple vehicles and thereby consisting of many parking spaces.

The remainder of this paper is structured as follows. Section 2 describes related work and Section 3 provides the fundamentals of the proposed solution on an abstract level. Section 4 describes the required changes considering an existing protocol. Section 5 gives an overview of the implementation and Section 6 concludes.

2 RELATED WORK

A number of the works about charging stations focus on location planning and charge scheduling. These are particularly important for distributing load and therefore increasing efficiency. (Hanabusa and Horiguchi, 2011) and (Hess et al., 2012) propose optimizations for charging station placement while taking distance to travel and waiting times into account. (Mehar and Senouci, 2013) deals with the same problem but considers additional factors to minimize deployment costs.

The work in (Timpner and Wolf, 2012) evaluates various scheduling algorithms for efficient utilization of charging stations in project V-Charge. Parking spaces with and without charging stations are man-

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aged by a future system where vehicles autonomously navigate as needed regarding the battery's state of charge. (Ruzmetov et al., 2013) proposes a platform where an electric vehicle is automatically assigned to a charging station based on parameters like the power level of the battery, distance to travel, and status of the road traffic. Moreover, the driver is guided to this charging station with a mobile application.

Open Charge Point Protocol (OCPP) 1.5 (OCPP Steering Group, 2012) is a standard open protocol for communication between charging stations and a central system that manages them. It defines message types for authorization of customers, starting/stopping charging of electric vehicles, configuration and reservation of charging stations. However, it lacks a mechanism for the management of parking spaces assigned to the charging station. On the other hand, (U.S. DOT, 2011) and (Litman, 2013) summarize current solutions in parking management but do not consider parking lots with charging stations.

3 APPROACH

This section describes our approach on an abstract level. The charging station is equipped with an occupancy sensor for each single parking space and each parking space is assigned to a socket of the charging station. Charging stations are connected to a central system. We modeled the contexts of a charging station as a set of states – *free*, *occupied*, *authorized*, *charging*, *warning*, *violated* – depending on three sources:

1. **Sensor Information:** Occupancy sensors can detect whether a parking space is *free* (no vehicle parking) or *occupied* (vehicle parking). Subsequently, the central system can be informed about the change.
2. **Customer Interaction with the Charging Station:** After a parking space is *occupied*, the customer must be *authorized* (allowed to charge) and start *charging* his/her electric vehicle (for example by plugging in the cable).

   We also added the state *warning* which implies that the vehicle has to leave the parking space:

   I. The charging station changes from *occupied* to the *warning* state, if the authorization fails.
   II. The charging station changes from *charging* to the *warning* state, if the charging process is stopped (for example by unplugging the cable).
3. **Timeouts:** In order to prevent misuses or abuses of the parking space we introduced time constraints for three states, *occupied*, *authorized* and *warning*. While a vehicle is parking, the customer must take actions within a fixed period of time so that the parking space is not blocked for a long time and the charging station can offer its service to others.

   I. In the *occupied* state, the customer must authorize himself/herself within a fixed period of time, otherwise the charging station changes to the *warning* state.
   II. In the *authorized* state, the customer must start charging within a fixed period of time, otherwise the charging station changes to the *warning* state.
   III. In the *warning* state, the vehicle has to leave the parking space within a fixed period of time, otherwise the charging station changes to the *violated* state. Changing to the *violated* state is the only transition where a network communication is essential since central system must be informed about the situation and additional steps should be taken (such as reporting to law enforcement officials).

   Timeouts are handled by each charging station internally, so the task will not be burden on the central system.

Figure 1 illustrates the functionality of the charging station with the states. It is important to note that state changes are managed by the charging station. This enables to continue using the functionality if the network connection fails and the charging station is not connected to the central system. Beside the obvious hardware-enhancement of including occupancy sensors, the solution proposes changes on the software of both the charging station and the central system. First, the charging station must be able to process information gathered by sensors and change states accordingly. Second, the charging station's internal processes must trigger state changes when authorization succeeds or fails, and when charging process starts and stops. Third, the functionality suggests a communication between the charging station and the central system.

Authorization. We made no distinction between different authorization mechanisms since the chosen mechanism does not affect the way state changes function. They all serve the purpose of allowing the customer to charge or not, hence trigger a transition

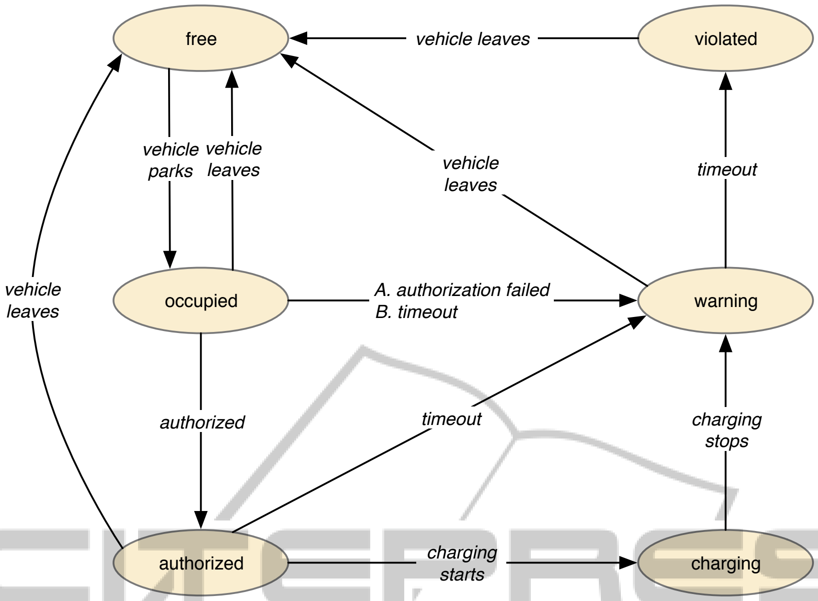

Figure 1: The state diagram of the charging station.

from *occupied* to *authorized* or to *warning*. Different operators may use different mechanisms such as phone calls, sending text messages, near field communication (NFC) with smartphones or radio-frequency identification (RFID) tags attached to membership cards, charging cables or even vehicles. In all mechanisms the customer is typically given an ID and during an authorization process it is checked whether the ID is registered in the database.

Reservation. We also made no exception for the reservation of a charging station for a specific customer. The reasoning is as follows: If a charging station socket is reserved for a specific ID, then only this ID will be authorized to charge and authorization of other IDs will fail even though they might be registered. On the other hand, if there is no reservation at that time, all registered IDs can authorize. The logical distinction between these two cases does not reflect on the implementation of state changes.

3.1 Color Codes

Each parking space features luminaries that code the states (Table 1). The color codes can be divided into two groups: Colors when no vehicle is parking and colors when a vehicle is parking. The first group of colors are intended to guide a customer in search of a parking space from a distance. The second group of colors serve the purpose of guiding the customer during the service of a charging station.

The *free* state has the extra conditions *ready*, *reserved* and *inoperative*. These can be set both by the charging station and the central system. If a charging station is *ready*, it is functional and available to charge for any one. If a charging station is *inoperative*, it is not functional and therefore not available for charging. If a charging station is *reserved*, there exists a reservation for a specific customer.

Table 1: Color codes.

State	Color
free & ready	green
free & reserved	yellow
free & inoperative	red
occupied	blink green
authorized	blink yellow
charging	yellow
warning	blink red
violated	red

The choice of the color scheme based on three criteria: The number of colors should be kept at minimum in order to not confuse the customer. Second, the colors should be distinct from each other so that the customer can recognize them from a distance. Third, the universal association of colors with meanings should be taken into account. Several studies [(Dunlap et al., 1986), (Ryan, 1991), (Silver et al., 2002)] indicate that red has the highest perceived hazard level. Yellow has a medium and green has the lowest perceived hazard level. We complied with these findings in order to prevent a learning curve or making the customer think about what each color represents. Additionally, the states with timeouts are coded as blinking colors for an emphasis.

3.2 Example Scenarios

This section embodies two use cases where offline behavior of the charging station is excluded, i.e. the charging station is connected to the central system.

Figure 2 illustrates a scenario where the customer is registered or has a reservation. After the vehicle parks, the charging station automatically changes to the *occupied* state, the timer starts and a message is sent to the central system. The customer requests authorization in time with the mechanism that the charging station supports. In this case, the charging station has an integrated RFID reader and the customer passes his/her card in front of the RFID reader. The system grants authorization, the charging station changes to the *authorized* state and the timer starts. The customer plugs in the charging cable in time, charging process starts and the charging station changes to the *charging* state. After the battery is charged or if the customer wishes to interrupt the process, he/she can unplug the cable and the charging station changes to the *warning* state. A timer starts and the vehicle has to leave the parking space. But the timer elapses and the vehicle is still parking. In this situation, another message is sent to the central system about the violation of terms of use.

Figure 3 illustrates a scenario where the customer is not registered or is not the reserved customer. After the vehicle parks, the charging station automatically changes to the *occupied* state, the timer starts and a message is sent to the central system. The customer requests authorization in time but the system does not grant authorization. The charging station changes to the *warning* state and the timer starts. The vehicle leaves the parking space in time, so there is no violation. A message is sent to the central system to inform about the new status.

4 THE PROTOCOL

This section describes how our approach can be utilized in an existing communication protocol between charge points and a central system. For this purpose we chose to demonstrate how the OCPP 1.5 can be extended in order to support parking lot management. It is to be implemented with Simple Object Access Protocol (SOAP)[1] over HTTP for minimal overhead and in order to maintain consistency since OCPP uses the same two protocols. As with OCPP, the extension uses Web Services Addressing[2] and contains a

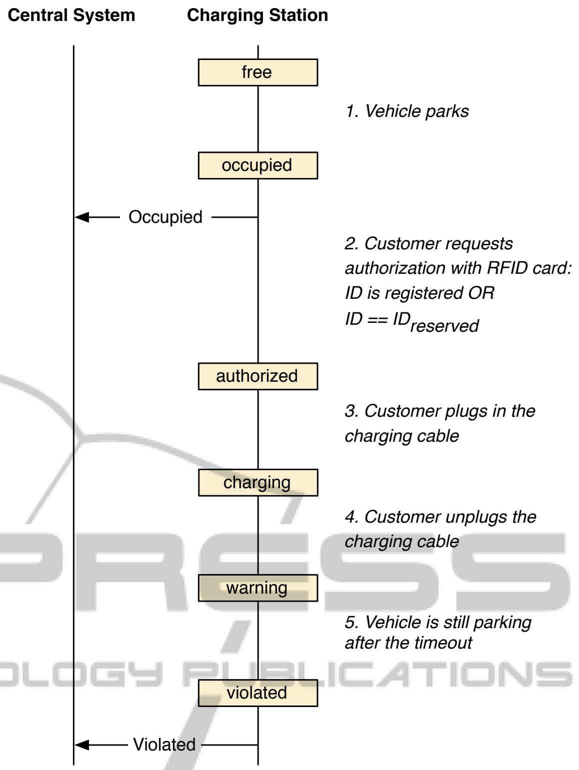

Figure 2: Customer is registered or has a reservation.

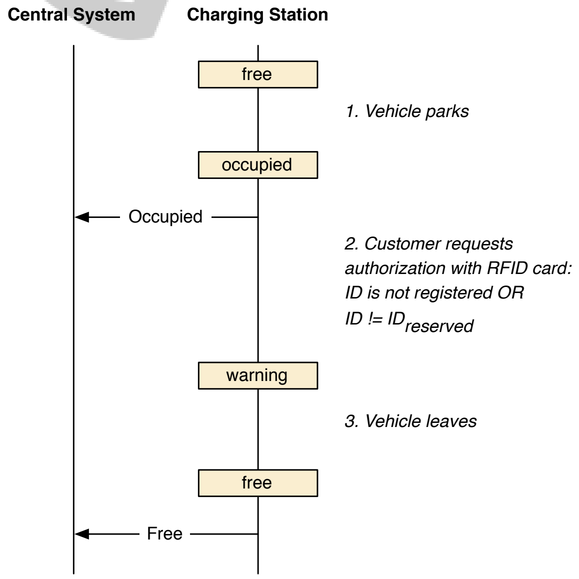

Figure 3: Customer is not registered or is not the reserved customer.

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[1] SOAP is a specification for encoding messages that are exchanged in computer networks.

[2] Web Services Addressing is a specification for conveying addressing information of the sender and receiver in SOAP messages.

chargeBoxId element in the SOAP message to identify the charging station.

4.1 Operations Initiated by the Charging Station

In the following we present the necessary changes to the protocol and how existing implementations should be modified in order to support parking management for the operations initiated by the charging station.

4.1.1 Protocol Changes

While automatically changing from one state to the another, the charging station informs the central system about the status of a parking space so that the central system keeps track of changes. Therefore a new operation, *InformParking*, should be initiated by the charging station. We opted only to use the field *connectorId* (the socket identifier) rather than a parking space identifier or sensor identifier since the mapping between these three entities should be unique. The mapping from sensor identifier to parking space identifier to socket identifier should be taken care of by the charging point internally and is of no interest for the central system. Additionally, using *connectorId* preserves integrity since OCPP already contains the definition of this field.

1. InformParking
   - Request:
     - connectorId : int
     - timestamp : dateTime
     - status :
     (a) Free
     (b) Occupied
     (c) Violated
   - Response: *Empty response*

4.1.2 Implementation Changes

Furthermore, the implementation of existing operations in charging station must be extended in a way that they trigger state changes.

- Authorize: If the ID of the customer has been accepted, charging station changes from *occupied* to the *authorized* state, or to *warning* otherwise.
- StartTransaction: If the transaction starts, charging station changes from *authorized* to *charging* state.
- StopTransaction: If the transaction stops, charging station changes from *charging* to *warning* state.

4.2 Operations Initiated by the Central System

In the following we present the necessary changes to the protocol and how existing implementations should be modified in order to support parking management for the operations initiated by the central system.

4.2.1 Protocol Changes

Operations initiated by the central system require minimal modification to support the new functionality. The existing operation *ChangeConfiguration* is extended with following new configuration keys:

1. occupiedTimeout : int
2. authorizedTimeout : int
3. warningTimeout : int

As described in Section 3, these configure the maximum period of time in seconds a charging station can be in *occupied*, *authorized* and *warning* states before it times out. Analogously, the existing operation *GetConfiguration* is extended with the same configuration keys to retrieve the value of the three timeout settings.

4.2.2 Implementation Changes

When the central system invokes the operations *RemoteStartTransaction* and *RemoteStopTransaction* and the charging station accepts to execute them, it should change to *charging* and *warning* states, respectively. Additionally, when the central system invokes the following operations at the charging station, they set the extra conditions for the *free* state. So the implementation of the charging station must be extended to support them.

- ChangeAvailability: If the charging station is able to change to the requested type *Inoperative*, this corresponds to the condition *inoperative*. If the charging station is able to change to the requested type *Operative*, this corresponds to the condition *ready*.
- ReserveNow: If the charging station accepts the reservation, this corresponds to the condition *reserved*.
- CancelReservation: If the charging station is able to cancel the reservation, this corresponds to the condition *ready* and the charging station is available to charge for any one.

5 IMPLEMENTATION

This section describes the hardware and software implementations for our solution.

5.1 Hardware

We evaluated three sensor types to monitor the charging station surroundings: A photoelectric laser sensor, an ultrasound sensor and an inductive loop.

The photoelectric laser and ultrasound sensor share the same operating principal. They feature a sender, which emits a signal that is reflected by an object, and a receiver, which detects the reflected signal. This is then interpreted as an object being nearby. In the case of the photoelectric laser sensor this signal is a beam of light, and in the case of the ultrasound sensor this signal is a sound wave with a high frequency. The photoelectric laser sensor is not cost-efficient to be installed in large scales by operators. Furthermore, this sensor demands direct viewing angle to the object, so the installation is inconvenient since it has to be placed above the charging station. Having the sensor outside would endanger the functionality. Another drawback was that the sensor could detect a nearby object but not the object type. Our evaluation showed that the ultrasound sensor had the same issues. So these two sensors are not suitable for the charging station setup.

The best fitting solution was the inductive loop, but it is also very elaborate to install. An inductive loop utilizes magnetic fields to sense when a large metal object, such as a vehicle, is nearby and causes a change in the frequency of the electrical current. Then, this change is recognized by the detector. The detectors are tested and evaluated, and are able to successfully detect and inform about the occupancy status changes. Thus, we opted to install inductive loop vehicle detectors under the parking spaces assigned to the charging station that is deployed at our university.

5.2 Software

We have integrated the proposed changes into our own OCPP central system implementation *SteVe*[3]. Therefore we were able to extend and modify the implementation as required. SteVe is an open source project that supports OCPP 1.2 and 1.5. It is a Web application designed to run under Apache Tomcat and consists of multiple Java servlets. It uses the Apache CXF[4] framework for creating and receiving SOAP messages. Moreover, CXF supports Web Services Addressing. SteVe was tested successfully in operation.

A prototype software for the charging station has been developed that implements our approach. It is an implementation of the the diagram in Figure 1 as a finite state machine, that supports collecting sensor information and changing LED colors according to the state change. The communication between the charging station that is running an implementation of OCPP and SteVe is currently a subject of work in progress.

6 CONCLUSION

We presented an integrated solution for managing parking lots with charging stations since the existing solutions are exclusive to either parking management or charging station management. Our approach enables the parking spaces to be occupied only by authorized electric vehicles. This is achieved by tightly monitoring and controlling user interaction with the charging station. In addition, charging stations are equipped with luminaries that guide customers in search of a parking space and during the actual use of the charging station.

Future work consists of evaluating and improving our proposed system based on user-centric field tests. The architecture of our system paves way to publish parking availability of the charging stations via the Internet for drivers to check by mobile devices before arriving at their destination. This is due to the fact that the central system keeps track of the parking changes and the user interaction. Furthermore, the currently-only-visual guidance system can be extended by installing speakers in the charging station in order to provide aural assistance during the use of the charging station. This would improve the perception of state changes, timeouts and the run of the timer.

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[3] abbr. for SteckdosenVerwaltung (English: *socket administration*) https://github.com/RWTH-i5-IDSG/steve

[4] http://cxf.apache.org/

[5] Bundesministerium für Wirtschaft und Technologie (BMBF) http://www.bmwi.de/

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