Development of a Service Architecture of en-route Electric Vehicle Charging*

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Abstract. This paper designs a tour planning service framework for electric vehicles which want to visit multiple destinations and need to be charged during their trips. Considering long charging time and insufficient available charging facilities, the visiting order is important to the waiting time of a tour. A mobile application is developed on top of Android operating systems, interacting with the Google map service for basic display of geographic information. After capturing the destinations selected on the map, the mobile application requests the visiting order to our tour planning server. Then, approaching each destination along the recommended route, the point-to-point path finding requests are invoked sequentially. For the efficient integration of new services, the tour planning services are implemented via the web service mechanism in the .NET platform.

Keywords: electric vehicle, multidestination tour, charging plan, web service, waiting time

1 Introduction

Nowadays, just like other smart grid entities, electric vehicles, or EVs in short, are highly likely to be empowered by computational intelligence developed in information and communication technologies [1]. In spite of energy efficiency and many other benefits, their driving range is less than 100 *km* and it takes about 6 ~ 7 hours to fully charge a single EV with a slow charger. Even the average daily driving distance can hardly exceed this range for ordinary EVs, rent-a-cars and delivery vehicles can drive beyond this capacity. In the mean time, intelligent computer algorithms can alleviate this problem by finding an energy-efficient route and charging plan [2]. For example, the well-known TSP (Traveling Salesman Problem) can be adapted for this purpose and its service can be provided to EVs via well-eveloped computer communication mechanisms.

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The rent-a-car users, generally tourists, stay at a tour spot to take a tour, during which EVs can be charged as long as the spot installs charging facilities. The amount of chargeable electricity is limited by the battery capacity even when tourists stay at a spot for a very long time [3]. On the contrary, if the remaining battery amount is not sufficient, the EV must wait until it will be charged at least enough to reach the next destination. This waiting time is the most critical source of inconvenience for EV users. Hence, this paper designs an intelligent route service framework for EVs driving multiple destinations. This design necessarily incorporates the available information technology components such as Google map API, web services, and wireless communication mechanisms. The popular interfaces enable the component to efficiently cooperate with each other, allowing additional components to be combined with our framework.

2 Service Platform Design

Figure 1 outlines our service framework. Each mobile device, moving along with an EV, can access the Internet via WLANs or cellular networks. It can be an in-vehicle computer device or a smart phone carried by a driver [4]. The mobile application has two connections, one to the Google map service and the other to our route planning service. Basically, underlying map images and associated methods are provided by the Google map service. The Google map also allows users to select a set of locations they want to visit on the map. Catching the user input, our mobile application gets the coordinates of the selected spots in the WGS84 coordinate system, finds the predefined tour spot identifiers, and sends them to the route planning service.

The route planning service has two important interface functions, one for visiting order decision and the other for inter-destination route finding. The interface invocation is conducted via the web service mechanism using SOAP (Simple Object Access Protocol). So, the service functions are implemented by means of the C# language on .NET platform. This function decides the visiting order for the given set of selected destinations. It is called before an EV starts the multidestination trip. The mobile application gets the sequence as a web service response and stores in its local memory. Now, it issues point-to-point route planning requests one by one along the route every time the EV approaches a destination.

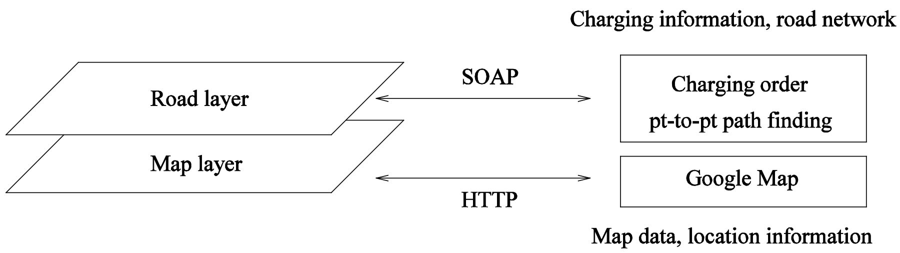

Fig. 1. Service architecture

Figure 2 illustrates the operation of mobile applications. Here, each application is aware of its location via the GPS receiver installed in the device. In our implementation, the device installs Android operating system. After getting the sequence, the EV issues a request for a point-to-point route between the first and the second destinations, denoted as *A* and *B* in the figure. When the EV approaches the destination of the route piece, the mobile application issues a route planning request for the next destination pair. In this example, the EV retrieves the route from *A* to *B* and is now on the way to *B*. Getting close to *B* (marked by a dotted circle), it issues the route planning request from *B* to *C* before the vehicle enters the path from *B* to *C*. Actually, for the accurate estimation of the current location, it is necessary to run a map matching algorithm in the mobile application, but the road network can be hardly embedded in the device application, it calculates Euclidean distance to decide whether an EV is inside the circle.

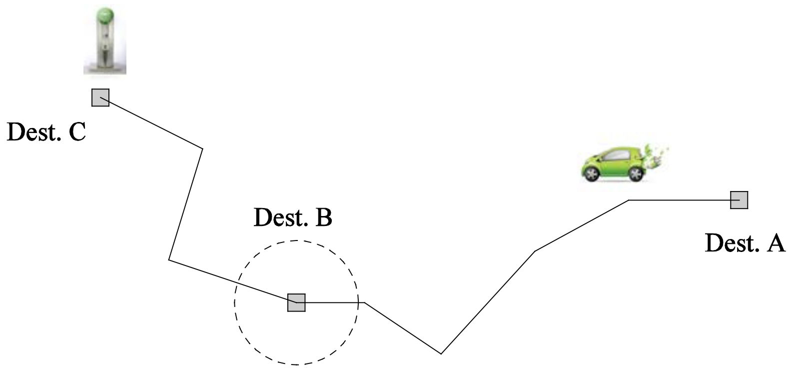

Fig. 2. Invocation of point-to-point route finding services

The route server maintains a road network and shares the destination identifiers with mobile clients. The server is aware of inter-destination distance and availability of chargers via the offline calculation. However, real-time information can be also combined to this server by continuously updating the link cost, if we are to take into account the travel time. The visiting order service is usually invoked before a multi-destination trip starts, so the user can wait by several seconds. Hence, this service can run backtracking-based search to find an optimal schedule which reduces the travel distance and waiting time induced by EV charging. The details on the idea of visiting order decision can be found in our previous work [5]. Next, the point-to-point rout can be found by the well-known A* algorithm. As this function can be called many times from many EVs, it is necessary to compute the route as fast as possible. Moreover, some common routes can be cached for the even faster response.

Finally, Figure 3 shows the implementation of the mobile application, which is targeting at Jeju city area, Republic of Korea. This area is a very famous tour place and installs about 3 hundred EV charging facilities. We select the 40 selectable visiting tour spots, assign identifiers to them, and investigate whether a spot has chargers or not. On the Google-generated map of Jeju city, the tour route is represented in the road network layer. Two end points are the two adjacent destinations of a total tour plan. The small rectangles are important intersections along the route. The route can be zoomed in to display the path details to the driver.

Fig. 3. Implemented mobile applications

3 Data Acquisition and Training

The drawbacks of EVs in short driving range and long charging time, can be alleviated by sophisticated computer algorithms and communication protocols. This paper has integrated a backtracking-based routing service for multiple destinations as well as an A* point-to-point route planning service, providing the EV users via the Google map API and the web service mechanism. Its extensibility can accelerate the deployment of EVs in rent-a-car business, especially in the tour place preferring eco-friendliness.

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