Web Service-based tour-and-charging Scheduler Framework for Rent-a-car Systems Employing Electric Vehicles

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Abstract

This paper presents a flexible service framework for tour-and-charging schedulers based on web services, aiming at providing an energy-efficient tour schedule services to electric vehicles. For a rent-a-car system which is a promising business model capable of dealing with high cost of electric vehicles, this service decides the visiting order for renters who want to visit multiple tour spots and need to have their vehicles charged during their trips. Mobile applications, running on Android operating systems, take the user selection via Google Map interface and submit to the scheduler by means of well-known Simple Object Access Protocol (SOAP). The tour scheduler implements not only a genetic algorithm to decide the visiting order for the given spot set but also a point-to-point A algorithm to find an appropriate route between two consecutive spots on a graph-style road network, which necessarily contains the locations of charging facilities. Every parameter and result is encapsulated by KSOAP to comply with .NET platform. This service can enriches the smart transportation service, especially in long-term and short term rental and sharing businesses.*

Keywords: *electric vehicle, multi-destination tour, charging plan, web service, waiting time*

1. Introduction

In smart grid cities, both central and distributed coordinators are controlling the activities of a variety of power entities, pursuing energy efficiency and smart power consumption [1]. Those entities are belonging to smart places, smart renewable, smart transportation, and the like. For example, electric vehicles, or EVs in short, are the key element in smart transportation. Such a goal can be first achieved by computational intelligence for the facility management in power generation, transmission, distribution, and consumption [2]. Moreover, advanced communication technologies and sophisticated information technologies make it possible for heterogeneous power entities to seamlessly interact with one another and promptly respond to external condition changes [3]. This coordination includes many optimization strategies such as scheduling appliance operations, planning electricity network facilities, allocating relevant resource, and manipulating big data based on cloud computing frameworks [4].

As for smart transportation, EVs play a key role, as they cannot only achieve energy efficiency but also reduce greenhouse gas emissions. Hence, EVs are expected to replace gasoline-powered vehicles some time, and many eco cities are much interested in the deployment of EVs and the integration of renewable energies to EV charging.

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However, it doesn't look easy for EVs to promptly penetrate into our daily lives as they are too expensive yet for personal ownership. Hence, kinds of sharing services are reasonable business models of EVs for the time being. First, short-term sharing lasts at most a few hours. It is a sharing service for commuters, shoppers, and other local residents [5]. Here, users rent out an EV at a sharing station and returns to the same or another station. In this case, the trip is not long and EV charging is done in sharing stations. Second, long-term sharing can possibly last for a few days, mainly preferred by tourists. The trip length is highly likely to exceed the driving range of EVs and renters are responsible for charging.

Another critical problem lies in long charging time, as their driving range is usually less than 100 *km* and it takes about 6 ~ 7 hours to fully charge a single EV with a slow charger [6]. Even the average daily driving distance can hardly exceed this range for ordinary EVs, rent-a-cars can drive beyond this range. In the mean time, EVs, just like other smart grid objects, can be empowered by computational intelligence developed in information and communication technologies [7]. Namely, intelligent computer algorithms can alleviate this problem by finding an energy-efficient route and making charging plans [7]. For example, the well-known TSP (Traveling Salesman Problem) solvers can be adapted to find an efficient visiting order, not just taking into account the distance criteria but also charging time during the trip. This adaptation includes the augmentation of charging time constraints for search space traversals and the redefinition of fitness functions for genetic algorithms.

The rent-a-car users, generally tourists, visit a set of tour spots, staying at each spot to take a tour. During their stay, their EVs can be charged as long as the spot installs charging facilities on parking lots. A tour plan can be generated either before the tour starts or during the tour. The amount of chargeable electricity is limited by the battery capacity even when tourists stay at a spot for a long time [8]. 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. To say nothing of high-speed computation in tour planning for better responsiveness, the tour-and-charging service must interact with EV clients, which can be mobile phones or in-vehicle telematics devices. Nowadays, there are several useful inter-object communication mechanisms like web services in the Internet domain [9].

Hence, this paper designs an intelligent route service framework for EVs driving more than one destination. This design necessarily incorporates the available information technology components such as Google map API, web services, and wireless communication mechanisms. According to the WC3 documents [10], as a lightweight protocol, SOAP (Simple Object Access Protocol) allows to exchange structured information in a distributed and decentralized environment, taking advantage of XML (eXternal Mark-up Language) technologies. In addition, Google map API enriches location-based applications on Android operating system platform stuffed with Google maps by default [11]. The popular interfaces enable the component to efficiently cooperate with each other, allowing additional components to be combined with our framework. As an extended version of our previous work [12], this paper includes related work and more details on implementation procedures.

In addition to the outline description of this work in Section 1, the rest of the paper is organized as follows: Section 2 introduces related work, focusing on some variants of TSP problems and their solvers. The routing service implementation is explained in detail in Section 3, focusing on service architecture and network connection. Finally, Section 4 concludes this paper along with a brief introduction of future work.

2. Related work

The tour-and-charging scheduler is a variant of the TSP problem in that tour places are visited once by a vehicle. The difference lies in that EVs don't have to return to the start place in tour scheduler. Nowadays, the TSP is generalized to the multiple TSP (mTSP), where not a single but multiple vehicles traverse the given set of places. It can be extended to a multiple day tour scheduler with a single EV. The cost function of this mTSP usually estimates the total traveling cost of all salesmen or the highest traveling cost among all salesmen. [13] proposes an evolutionary algorithm for the mTSP employing the restricted Boltzman machine-based estimation scheme. Most impressively, its encoding scheme adds (*m-1*) pseudo places where *m* is the number of salesmen to separate the respective visiting schedules. Pseudo places have negative integer values to be differentiated from ordinary places.

Another interesting TSP variant is the special TSP with intermediate cities [14]. In this problem, link weight, or cost, can change constantly and the TSP schedule must be recomputed on every change in the link weight. It also differs from the classic TSP in that not every city must be visited just like the selected TSP or orienteering problem [15]. This scheme exploits the All-Pairs-All-Paths algorithm for preprocessing. It removes a node from the set of intermediate nodes, retrieving all of the paths between the node and all other nodes. Then, a greedy algorithm gets the path of minimum weight from all of them. The fastest route is likely to change while a person is in his or her way to the destination. Their implementation assumes that a text message is sent to the drivers' cellular phones. Additionally, this work builds V2I (Vehicle-to-Infrastructure) framework in which each vehicle reports its location, heading, speed, and the like.

Our research team has been developing a tour-and-charging scheduler for Jeju city, which pursues an ambitious plan of replacing all internal combustion engine vehicles with EVs by 2030. On our service scenario, a traveler selects a set of tour spots. Basically, for every feasible schedule, it is possible to estimate the waiting time, considering the stay time at each spot and the distance between two spots [16]. If the number of spots is less than 11, the exhaustive search space traversal can find the optimal schedule within 1 second. Moreover, this service can cope with another user-issued requirement such as preferred restaurants [17]. However, to be scalable for the increased number of selected spots or to extend to multiple day schedules, suboptimal techniques, such as genetic algorithms, are needed [18]. Here, each schedule is encoded into an integer-valued vector and our scheduler iteratively runs genetic operations such as selection, crossover, reproduction, and mutation. The waiting time for EV charging is estimated in the fitness function.

3. Service Platform Design

3.1. Preliminaries

After being designated as a smart grid initiative country in 2009, the Republic of Korea launched the Jeju smart grid test-bed and is now pouring its effort to test leading-edge technologies and develop business models in 5 major areas consisting of smart power grid, smart place, smart transportation, smart renewables, and smart electricity services [19]. Particularly, in Jeju city, hundreds of EVs are driving and also hundreds of chargers are installed in shopping malls, charging stations, and tour spots. In this smart grid model city, every control scheme can be designed and implemented in TOC (Total Operation Center) as shown in Figure 1. For the sake of developing a city-wide information service for EVs, a new TOC server is being built to interact with EVs and charging stations. It will track the current location of each EV in the target area and also monitors the real-time status of charging facilities. This service system will provide intelligent information services, and emergency rescue services.

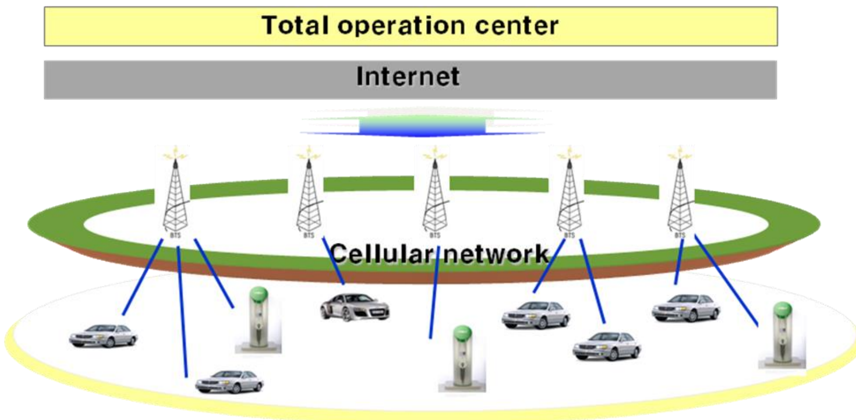


Figure 1. Inter-component connection

3.2. Overall service platform

Figure 2 outlines our service framework. Each mobile device, carried by a passenger and moving along with an EV, can access the Internet via WLANs or cellular networks. WLAN is used to invoke the scheduler service residing in TOC, before the trip starts, possibly in a hotel. Through this high-speed connection, the schedules can be downloaded to the mobile device and retrieved later during the trip. Some areas including restaurants install WLAN APs (Access Points) through which large bandwidth is available. In addition, cellular networks make it possible for EVs to interact with the server any time and any place they want. Its bandwidth is not so large as WLAN and it's not free. However, the cost is much reduced these days and the ubiquitous access is very attractive. On those networks, 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, finds the predefined tour spot identifiers, and sends them to the route planning service.

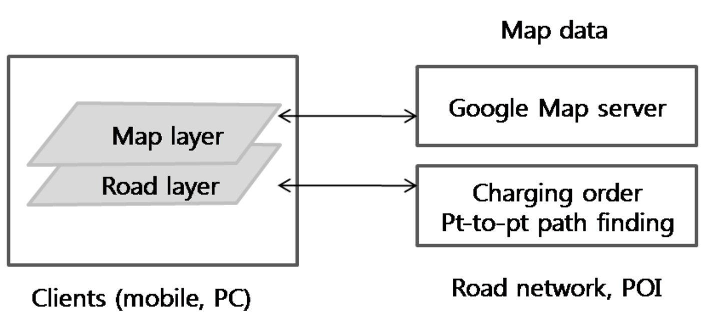


Figure 2. Service architecture

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. So, the service functions are implemented by means of the C# language on .NET platform using Microsoft Visual Studio. This function decides the visiting order for the given set of selected destinations. It is called before an EV starts the multi-destination trip, as will be explained later. 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. The mobile application is developed using Eclipse which supports Android Java projects. In addition, every component, such as road network, current EV location, and charging station locations, uniformly takes the WGS84 coordinate system. Hence, NMEA coordinates used in GPS receivers are converted to WGS84 coordinates.

Figure 3 illustrates the operation of mobile applications running on Android operating systems. Here, each application is aware of its location via the GPS receiver embedded in the mobile device. After getting the visiting order before the trip from our schedule service, the application works in two ways for retrieving the series of point-to-point paths for consecutive spots. Here, each point-to-point path consists of a sequence of intersections along the route. First, all of them are calculated just after getting the visiting order and stored in the device. As the number of tour spots is at most 15 and the number of intersections in tour area is usually small, all of paths can be stored in the device. This scenario can be accomplished on high-speed WLAN connection. Second, each point-to-point path can be calculated each time the EV approaches a tour spot. This operation requires cellular network connection for ubiquitous network access and can benefit from real-time traffic information.

Next, as shown in the example of Figure 3, 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 a destination of the entire route, 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. The network distance is generally correlated with the Euclidean distance, so this work can work reasonably. Moreover, it is also possible to add information on the set of exceptional areas on mobile application.

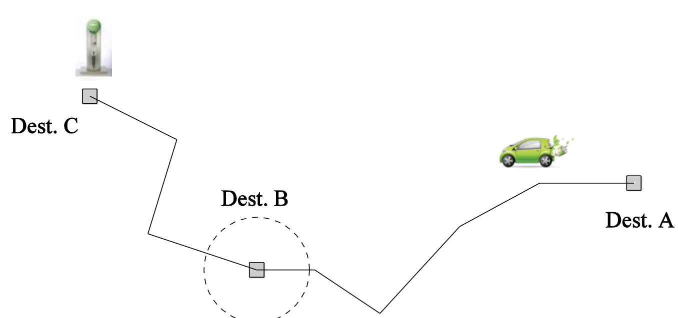


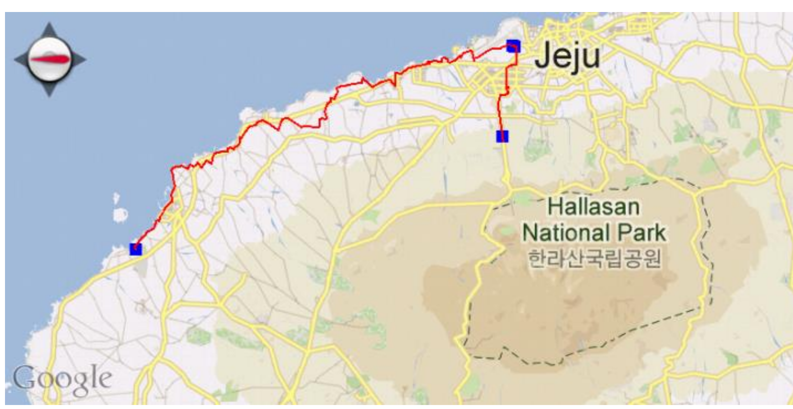
Figure 3. Invocation of point-to-point route finding services

3.3. EV service implementation

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. Here, genetic algorithm-based scheduler is implemented by defining a fitness function which estimates the waiting time for a tour schedule. Each tour schedule is encoded to an integer-valued vector just like a typical genetic TSP solver. The details on the idea of visiting order decision can be found in our previous work [16].

Next, the point-to-point route can be found by the well-known A* algorithm [20]. 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. Sacrificing a little accuracy, A* can find a route within a reasonable time bound in a large road network. A* algorithm doesn't have to consider the waiting time for EV charging. For better efficiency, it is necessary to define a cost matrix between each pair of intersections. The cost can be distance, driving time, the number of traffic signals, and the like. The driving time is most common, and it can be dynamically updated from real-time traffic information services with a given period.

(a) Basic interface



(b) Zoomed in and retrieved route on the route

Figure 4. Implemented mobile applications

Finally, Figure 4 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 as shown in Figure 4(b). As for our run time environment, it must be mentioned that the execution time on .NET platform brings not a little overhead. Hence, our implementation pursues speed-ups via off-line computation as much as possible. Moreover, predefined tour spot ids avoid additional overhead in finding the closest node from a specific point with the Euclidean distance comparison every time the service is invoked.

4. Conclusions

EVs are the most important component in smart transportation, but they have drawbacks of high cost and long charging time. Hence, it is necessary to provide an energy-efficient tour schedule service for an EV-based rent-a-car system, which is considered to be one of the most promising business models to cope with their high cost. This paper implements the tour-and-charging scheduler and then builds the service framework using the well-known components such as .NET, SOAP, and Android operating systems. Above-mentioned can be alleviated by sophisticated computer algorithms and communication protocols. It has integrated a genetic algorithm-based routing service for multiple destinations as well as an A* point-to-point route planning service, providing useful information to EV users via the Google map API and the web service mechanism. Its extensibility can accelerate the deployment of EVs in the rent-a-car business, especially in the tour place preferring eco-friendliness.

The common availability of exploited tools and components makes it possible to flexibly integrate a new service to the electric vehicle services and enrich the relevant business models. As future work, we are planning to develop a real-time tracking system for EVs for the purpose of providing such information to drivers as available chargers along the route, current reservation status of charging stations, and the like. Moreover, the battery dynamics along the route can create valuable information for the study of EV battery discharge model according to the road characteristics [21].

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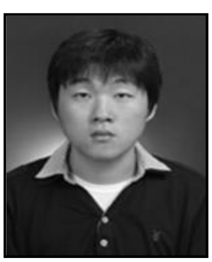

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