Bulletin of Networking, Computing, Systems, and Software – www.bncss.org, ISSN 2186–5140
Volume 1, Number 1, pages 54–55, January 2012

Availability of DMB channels for EV charging

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***Abstract*—This paper addresses the availability of digital multimedia broadcasting to provide better charging services to electric vehicles. Through the advertisement framework which has been implemented by an extended TPEG frame and is capable of updating current waiting time in each charging station within a few second, the broadcast can eliminate multiple information retrieval requests from a lot of vehicles. The in-vehicle application first selects the candidate stations based on remaining battery and its current location. The uplink channel can be connected by either the cellular network or WiFi interface, if necessary. Then, the charging time estimation and time overhead for detour is evaluated to select the best one. Due to the delay in information posting, there can be inconsistency between the posted and the actual waiting time. The experiment shows that the inconsistency ratio is not so significant if charging stations are sufficiently available.**

I. Introduction

[1] Electric vehicles, or EVs, have many advantages over gasoline vehicles such as pollution reduction and energy efficiency. However, due to the limitation in the driving distance, they must be charged more often and the charging time is longer than gasoline vehicles. Meantime, EV telematics services can help to relieve such range anxiety by providing current information on charging station availability, estimated service time, and the like. As EVs select the charging station having the smallest queue length, this service can ideally distribute EVs to be charged over the stations in vicinity, reducing the average charging time. For EVs to benefit from the telematics service, a vehicle-to-server communication is indispensable. Considering that road-side gateways are not so commonly available, the cellular network and the WiFi connection will be the practical solutions for the vehicle-to-server interaction just like other mobile applications.

However, the cellular network is not free of charge and suffers from limited bandwidth, while the WiFi connection has the problem of frequent disconnection. Accordingly, it is desirable to add another communication channel, if available. In some areas, the DMB (Digital Multimedia Broadcasting) channel is in service and many vehicles have DMB receivers. It can broadcast information to the vehicles on the move over the vast area [1]. Particularly, terrestrial DMB works even in vehicles moving up to 120 kmh. However, DMB lacks interactivity with the users, as it is originally designed for one-way broadcasting. Interaction with charging stations and drivers on the move must be solved first. In the mean time, our previous work has designed and implemented a DMB-based advertisement facility which allows an advertiser to update his or her broadcasting contents via the Internet [2]. The update time is less than 10 seconds and it is possible to post the current status of EV charging stations in this system.

Figure 1 illustrates how the DMB facility works. To begin with, the contents server is located and managed in the Internet domain. The advertiser can modify the contents via the Web interface. The created contents are sent to the provincial DMB facility via the reliable and high-speed optical fiber network, as shown in the bold curve in the figure. The data service domain can be spatially separated from provincial DMB stations. The DMB station decides the local schedule and converts the contents to the TPEG (Transport Protocol Expert Group) frame to transmit via the local DMB channel. The DMB receiver catches the DMB signal from the transmitter, decodes the TPEG frame, and finally plays the content to the in-vehicle monitor device according to the content type [3]. Here, TPEG can support frames on road traffic message, public transport information, and location referencing. The implemented system defines an ADI (Advertisement Information) message, extending a TPEG message.

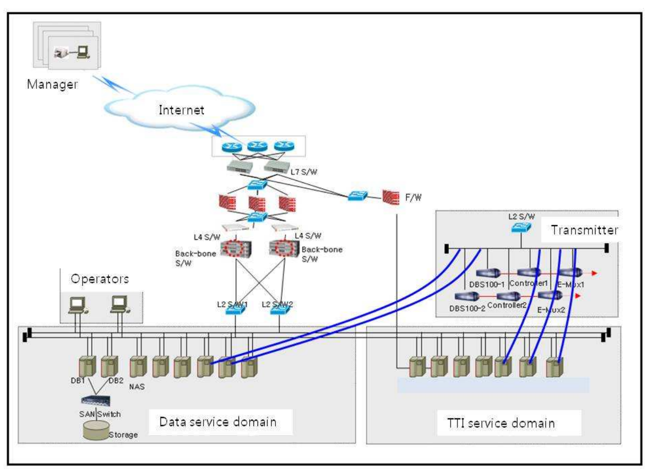

Fig. 1. DMB transmission architecture

[1]This research was supported 1) by KIAT under the Regional Industry and Technology Development Project, 2) by the MKE, Republic of Korea, under IT/SW Creative research program supervised by the NIPA (NIPA-2011-(C1820-1101-0002)), and 3) through the project of Region technical renovation.

II. Service Scenario Design

Figure 2 shows the proposed service scenario. First, charging stations marked by dark circles upload their queue lengths or other information mainly via the wired Internet connection. Now, they are broadcasted in the advertisement carousel via the DMB facility. Many telematics devices install DMB receivers for in-vehicle TV display. The digitally decoded DMB frame can be exploited by a telamatics application. In our system, 8 $kbps$ is allocated in the DMB carrier for the advertisement content. Even though this bandwidth is not sufficient for the image-based content, it is appropriate for the text-based contents. Moreover, the broadcast can alleviate per-EV information retrieval on charging stations from multiple EVs. An EV, which monitors its remaining battery and wants charging, alerts the driver. With current queue length posting, the driver may go to the station or an EV telematics application attempts to make reservation via the cellular phone or the WiFi carrier.

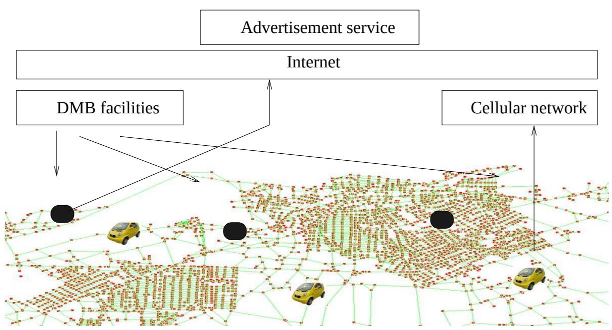

Fig. 2. Service scenario

For candidate station selection, the telematics application runs the one-to-may Dijkstra's shortest path algorithm on top of the embedded digital map in which the locations of respective charging stations are registered. It spans from the current EV location to the road network nodes reachable by the remaining battery amount, finding the stations in this range. Necessarily, if it gets sufficient stations, the search procedure can stop. For an EV located at C_{EV}, the driving time to D in case it is charged in charging station S_i will be calculated as follows. Namely,

$$F(S_i) = E_d + A^*(C_{EV}, S_i) + A^*(S_i, D) \quad (1)$$

, where $A^*(x, y)$ denotes the driving time from x to y estimated by A* algorithm [4], while E_d is the waiting time in charging station S_i estimated using the posted queue length.

However, due to the delay in the DMB-based posting, the information can be inconsistent with the actual queue length. As pointed out in the previous section, the posed information can be up to 10 seconds behind the current exact status. This inconsistency leads to unexpected waiting time for the driver. By a simple experiment, we can measure the probability of inconsistency based on the parameterization of station density and charging request interarrival time. The charging station density denotes the average number of charging stations at each moment an EV wants to charge. In addition, for a region boundary, we assume that charging requests take place according to the exponential distribution. Within the window of 10 seconds, if more than one request is directed to the same charging station, the inconsistency happens between posted and actual queue lengths, resulting in the mismatch in the waiting time prediction.

Figure 3 shows the inconsistency ratio according to the average interarrival time ranging from 1.0 to 20.0 seconds, with the station density fixed to 5. For each value, 100 request sets are generated and their results are averaged. Figure 4 plots the effect of the charging station density. The more stations, the better distributed EVs will be. Both experiments show that the inconsistency ratio is not so significant if charging stations are sufficiently available.

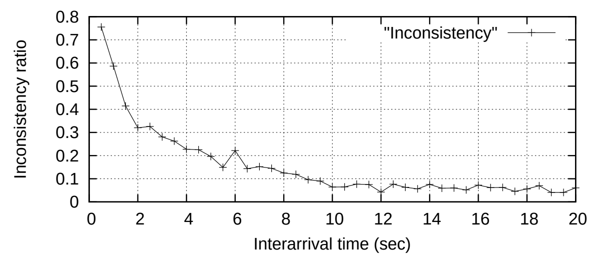

Fig. 3. Interarrival time analysis

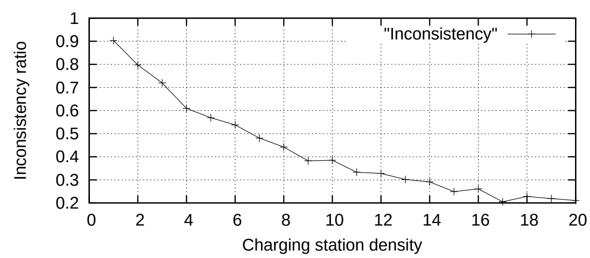

Fig. 4. Charging station density analysis

III. Conclusion

Facing the large employment of EVs, the availability of digital multimedia broadcasting can provide better charging services, taking advantage of prompt one-to-many data transfer. Based on this information, EVs can select the charging station which brings the smallest delay, so the charging load can be distributed over stations.

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