

Wireless Charging System Localization for Electric Vehicles Using RSSI

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ABSTRACT

Pedestrians A method of locating a charging target device (vehicle) in a parking lot scenario by the evaluation of Received Signal Strength Indication (RSSI) of the Dedicated Short Range Communications (DSRC) signal and Global Positioning System (GPS) data is proposed in this paper. A metric call Location Image (LI) is defined based on the RSSI received from each charger and the physical location of the parking associated to that charger. The central parking lot processor logs the GPS coordinates and LI received from the vehicle. Each pairing attempt by a vehicle loads a new LI into the central processor's database. Utilizing the LI and the proposed methods the vehicle will achieve expedited charger to system pairing while in the company of multiple chargers.

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INTRODUCTION

With the expected widespread offering of Grid Connected Electric Drive Vehicles (GCEDV) by automotive manufacturers the current efforts within industry are to provide plentiful and convenient methods for consumers to recharge their high voltage batteries.

In GCEDVs, sometimes referred to as plug in hybrid vehicles, on-board batteries are recharged by utilizing conductive means that adopt some standardized or proprietary convention. These conventions define the physical dimensions of the connectors, the handshaking data, as well as the energy transmission. The handshaking data establishes a one-on-one communication assurance to confirm the charger and vehicle unique identities. With this physical connection, this confirmation of pairing fidelity can be assured even in the most crowded parking lots. It is expected that the consumer will demand the same level of vehicle related user convenience that they have become accustomed to. This includes not having to remember to plug in their vehicle at every stop. A growing number of companies are developing charging systems that have the capability to charge a vehicle without any physical conductive connection. These systems are referred to as wireless charging systems. In the case of wireless charging of GCEDVs since the pairing confirmation is not assured by physical connection, a location and pairing process to establish a confirmed union between charger and vehicle must be employed.

SYSTEM DEFINITION

The SAE (Society of Automotive Engineers) has formed a taskforce on wireless charging and positioning of electric vehicles (SAE J2954). According to SAE J2954 the communications mechanism used in wireless charging will be Dedicated Short Range Communications (DSRC) defined in IEEE 802.11p [1]. This effort has been coordinated among the United States Department of Transportation (US DOT), SAE DSRC committee and the SAE communications committee. US DOT has several on-going projects

that are investigating utilizing DSRC for Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications for safety applications [2], [3]. The Federal Communications Commission (FCC) has allocated the spectrum from 5.850 GHz to 5.925 GHz, for DSRC operation in the United States [4], [5]. The DSRC spectrum consists of seven 10 MHz wide channels with a 5-MHz guard band at the low end (see Figure 1). Channel 178 is the control channel, which is generally restricted to safety communications only. The two channels at the edges of the spectrum are reserved for future advanced accident avoidance applications and high-powered public safety usages. The rest are service channels and are available for both safety and non-safety usage. Our proposed method in this paper is utilizing the DSRC and Global Positioning System (GPS) equipment available in the vehicle for V2V/V2I applications. We propose to use one of the available service channels in the DSRC spectrum. Our approach also requires GPS positioning with one half of a lane position accuracy which will be available in a V2V/V2I equipped vehicle. A recent study by the Crash Avoidance Metrics Partnership (CAMP) Vehicle Safety Communications 3 (VSC3) has compared relative positioning performance utilizing several GPS receivers available in today's market [6], [7].

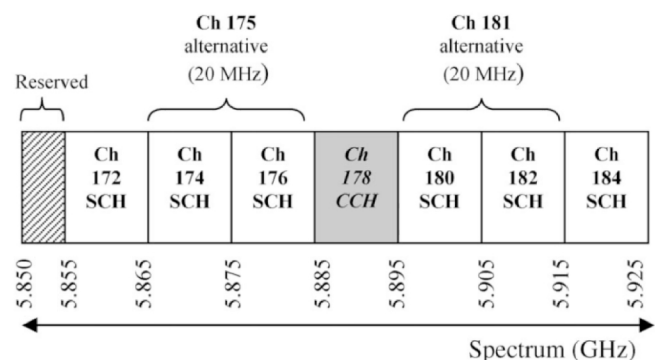


Figure 1. DSRC Spectrum



Documents

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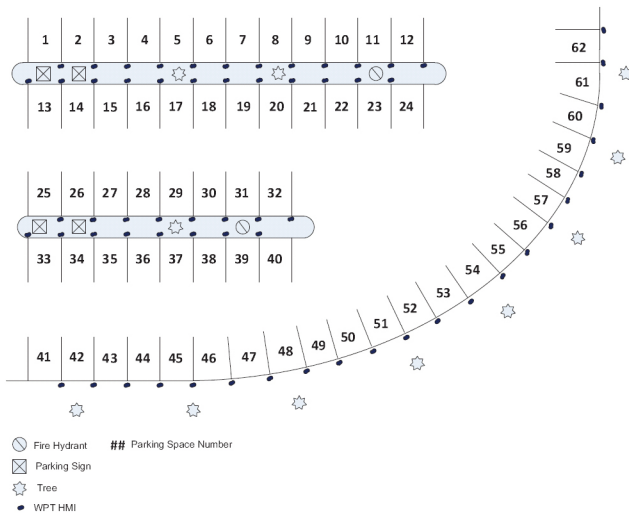


Figure 2. Parking lot with numbered parking spaces

The study showed that the lane classification is possible in most of the environments (e.g. within 1.8 meter across in 95 percent of times, lane width is 3.6 meter).

In this paper, Received Signal Strength Indication (RSSI) has been employed to create a channel model and positioning of the vehicle versus the charging station. While DSRC is performing its functions for safety purposes like vehicle to vehicle communications the antenna are powered at 20 dBm which provide a typical range of approximately 500 to 700 meters. The vehicle location process is simplified if the DSRC range is lowered so therefore a test was performed to identify a lower level antenna power that better suits this application's needs. Based on a charger wireless communication antenna power of 10 dBm, the charger communication will have around 20m range on flat paved surfaces. This range on a unidirectional charger interface unit's advertisement will reach approximately 60 parking locations as illustrated in [Figure 2](#).

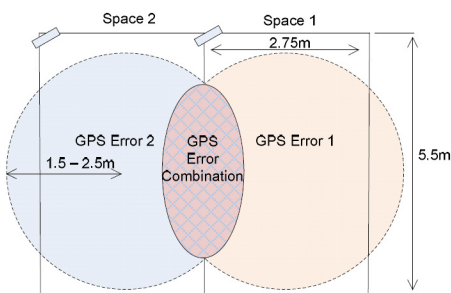


Figure 3. GPS Error in Parking lot space

[Figure 2](#) illustrates a parking lot that has wireless charging capabilities embedded under each of the parking spaces. A unique ID is assigned to each wireless charging unit allocated in the parking space. Each wireless charging unit periodically advertises itself to potential target vehicles if it is not already paired with a vehicle. We

propose utilizing the same DSRC module mounted in the vehicle for V2V and V2I applications. The wireless signal transmitted from the vehicle with the power of P_T and reaches the receiver (charging station) with received power P_R . The received power of the signal is highly affected by the environment and the level of deterioration can be calculated by Path Loss (PL). There are different models of propagation for calculating PL. The most simplistic method is Log Distance (LD) propagation model in which the power of the signal drops in logarithmic scale. Path loss may be due to many effects, such as free-space loss, refraction, diffraction, reflection, and absorption. In our study, we use the two-ray model to estimate the RSSI value.

Based on the data presented above the GPS error presents an unknown location radius that extends beyond the dimensions of a standard parking space as illustrated in [Figure 3](#). Due to the location unknown shown in [Figure 5](#), the vehicle location process must evaluate additional data beyond GPS coordinates to make a confident attempt and pairing confirmation. The wireless charging systems is embedded beneath the paving surface and located in the center of each parking spot in general use parking lots. Each wireless charging system will be connected to a user interface unit that is placed at the front left of each parking spot. This user interface unit will be used to display charger status, allow for payment, and allow for emergency stop. This user interface unit will also house the charger side DSRC wireless communication system and antenna. Each wireless charger user interface unit will be loaded with the latitude and longitude coordinates of the middle of the associated parking space.

GPS BASED LOCATION ESTIMATION

In situations that both the charging unit and the vehicle are equipped with operational GPS capabilities the wireless charging systems periodically transmit their respective addresses (via an HMI unit located in the front left of each parking location) relating to their physical location in the parking lot. The proposed method utilizes two metrics defined as following:

RSSI Score is value that is assigned to each charger in the communication range of GCEDV. Higher RSSI values get higher RSSI score.

Location Image is defined as a two dimensional mapping of RSSI score and the location of parking spot associated to the charger.

Once the vehicle is located in a parking space and is placed in park, the vehicle will assemble an array of the wireless charging pads that are within range of the wireless communication medium along with the RSSI score of each charger. [Table I](#). provides an example of the Location Image (LI) array that is assembled by the target vehicle. The target vehicle transmits this array, the vehicle's GPS coordinates, and the vehicle ID to the wireless charge location system.