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Traffic Modeling of a Cooperative Charge While Driving System in a Freight Transport Scenario

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Abstract

The aim of this paper is to present a research study on a traffic model developed for analysing the performance of the wireless inductive systems for charging while driving (CWD) fully electric vehicles (FEVs) from both traffic and energy points of view. The design assumptions of the developed traffic model are aimed to simulate in particular a freight distribution service in a fully cooperative traffic environment. In this case, the CWD service could be used to guarantee the minimum state of charge (SOC) of the batteries at the arrival to the depot that allows the vehicles to shortly start with further activities. In this way, the fleet manager could avoid wasting time for the stationary recharge, thus increasing the level of service of the freight distribution.

The CWD system is applied to a multilane ring road with several intermediate on-ramp entrances, where the slowest lane is reserved for the dynamic charging activities, when authorized vehicles are present. A specific traffic model has been developed and implemented adopting a mesoscopic approach, where vehicle energy needs and charging opportunities affect drivers' behavior. Overtaking maneuvers, as well as new entries in the CWD lane of vehicles that need to charge, have been modeled by taking into account a fully cooperative driving system among vehicles which manages adequate gaps between consecutive vehicles. Finally, a speed control strategy in which vehicles can be delayed to create an empty time-space slot in the CWD lane, is simulated at a defined node. This type of control, though is simulated to allow extraordinary maintenance operations, which may require a free charging zone for a given time slot, could also be applied to support merging maneuvers for on ramp vehicles.

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Keywords: Charging While Driving; traffic simulation; multi-lane road modeling; electric freight vehicles

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1. Introduction

The majority of fully electric vehicles (FEVs) currently satisfies the electric energy needs for motion with an on-board battery. The extensive literature on FEVs includes discussions of the following: battery problems particularly concerning limitations in size and power, their weight, life and recharge time and the lack of charging points. These problems are even more relevant for freight distribution services, where the masses and the distances travelled are relevant and where the stationary recharge would require many charging stations. However, electric vehicles could represent one of the possible solutions to low air pollutants emissions in the city centers, where a freight distribution service often has to deliver. For this reason, the charge while driving (CWD) system could represent a technology to contain the batteries sizes and the recharging infrastructures costs without impacting on the vehicles autonomy.

In particular, Boulanger at al. (2011) analysed the problems related to battery charging management, the uncertainty surrounding the monitoring of the state of charge (SOC), the limited availability of charging infrastructure and the long time required to recharge; problems that have generated range anxiety. The use of intelligent transport systems (ITS), in particular vehicle to vehicle or to infrastructure (V2X) communications, was evaluated to allow drivers to accurately and confidently locate charging stations where they could recharge the battery in the shortest amount of time (Ezell, 2010). Johnson at al. (2013) evaluated how connected vehicle technologies can facilitate the rapid charging of FEVs at charging stations throughout the road network. The market acceptance of FEVs, travel needs and consumer choices, particularly for the first car in the household, were also analysed by Kirsch (2000). Moreover, extensive research has claimed that the challenges of battery inefficiency and the large and wasted space in the FEVs can be overcome by the wireless power transfer (WPT) technology. This technology electrically conducts energy from a source to an electric device without any interconnecting mediums (Palakon et al, 2011). Finally, another important element that supports a battery charging modality with frequent and low energy transfer while driving is that the SOC must be managed carefully and the batteries should never be fully discharged to avoid an excessive shortening of the battery life cycle.

The aim of this research study is to provide a method to support preliminary studies about one of the possible future technology that could contribute to use FEVs in freight transport. One of the goals of the European white paper is to achieve essentially CO2-free city logistics in major urban centers by 2030 and CWD technology could represent one of the possible ways to reach this target. The model can simulate the performance of the wireless inductive charge of the electric vehicles while driving, from both traffic and energy points of view. Beginning with an electric vehicle supply equipment (EVSE) layout defined and analysed in a previous study (Deflorio et al, 2013), a model for the traffic flow simulation is implemented to quantify and describe traffic performance, useful for drivers and operators, but also the electric power that should be provided by an energy supplier for a proper management of the charging system.

2. The CWD service for freight vehicles and the technological scenario

The following paragraphs are aimed at providing a brief overview on how a CWD service based on assumptions and system requirements defined in the eCo-FEV project (2013) operates.

A driver who wants to use the CWD service should send a request, even automatically, to the charging station operator through an on-board unit (OBU). After the verification of operational requirements, the charging station operator returns the confirmation message to the user and updates the list of authorized vehicles, while the driver receives the authentication on the OBU. The CWD system should include some enforcement functions to prevent unauthorized vehicles from using the reserved lane. The position of each authorized vehicle is monitored along the CWD lane to switch on only the coils under the vehicles, thus avoiding energy wasting. The correct position monitoring is important also for vehicles outside the CWD lane because they affect overtaking maneuvers. The service should consider different classes of vehicles, according to their energy needs. Different speeds should therefore be admitted in the CWD lane and overtaking maneuvers should be managed according to a cooperative system among vehicles: advanced driver assistance systems (ADAS) guide drivers during their maneuvers and the cooperative system eventually intervenes on vehicle speeds to maintain the required gaps in the vehicle flow. This technology could serve both passenger vehicles – private or public – and freight vehicles for distribution services, on which this paper is focused.