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EVE: Fully Electric Vehicle Traffic Simulator for Technological Validation and Decision Making

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Abstract

This paper introduces a novel Fully Electric Vehicle Traffic Simulator that enables the technological validation and support to decision making procedures when deploying Fully Electric Vehicle Infrastructures and Efficient Cooperative route planning in Smart Cities context. One of the main objectives of Smart Cities platforms and infrastructures is increasing energy efficiency and reduce carbon emission, above all in Logistics and Transportation, and the wide adoption of Fully Electric Vehicles and associated energy efficient route planning and charging paradigms is crucial to achieve these objectives. At the same time, there is the need of tools that can support the real deployment and implementation of these services into real Smart Cities scenarios: this is motivated by the fact that sophisticated traffic simulation tools that are able to simulate the impact of Fully Electric Vehicles into real scenarios are not yet available in the market and the tool that we propose in this paper has the objective of covering this technological gap. The results that we present in this paper are the outcomes of research activities performed in the FP7 project EcoGem and of the early activities of the ACCUS and EMERALD projects.

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Keywords: Fully Electrical Vehicle, Traffic Simulator. Technological Validation, Decision Making.

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1. Introduction

Through this paper we will introduce the advantages that the use of specific traffic simulation capabilities can suppose in the technological validation and decision making procedures of deploying the electric vehicle concept in a Smart City. In order to reach these results we will use EVE, a Fully Electric Vehicle capable traffic simulator that is currently under development by the company HI-Iberia. EVE is a Fully Electric Vehicle capable traffic simulator whose concept was born from the FP7 project ECOGEM (http://www.ecogem.eu). In the frame of ECOGEM, EVE was designed and developed based on Open Source SW in order to support the verification of the platform performance for synthetically generated traffic scenarios to validate the advantages of using efficient ECOGEM routing vs. traditional routing.

The platform is under additional evolution under the aegis of the JTI Artemis project ACCUS (http://projectaccus.eu), where EVE will be incorporated within a real time traffic information platform within the Smart Cities context, and will be further improved in the framework of the FP7 project EMERALD (http://www.fp7-emerald.eu) where EVE will be integrated in the management of recharging point infrastructure as a planning tool, queue management, demand prediction tool.

As a result EVE will, once it is fully operational, feature the following characteristics: high performance, modular design and open interfaces that allow its easy integration into third party system; cloud based, easiness of access and operation; availability of different operation modes (only FEV, only traditional Internal Combustion Engine (ICE) or mixed); highly customizable in terms of simulation parameters, environmental values, types of vehicles, schedule, etc through a easy to use User Interface; ability to simulate recharging point infrastructure demand and planning recharging points locations..

2. Smart City Context

The availability of a FEV traffic simulation tool that is able to support decision making processes for the introduction of traffic monitoring, control and prediction policies and infrastructures is of major importance within Smart City's context. First of all, it would help solving main challenges of Sustainable and Green Mobility providing a means to assess Smart Mobility services and Smart Environment solutions.

By providing the simulation of FEV related traffic and energy consumption scenarios, EVE can be a traffic information provider for existing Intelligent Transport Systems. This is a crucial aspect in Smart Cities as it would contribute in enabling real time online services for traffic management and control, offering a greater flexibility and performance of the current functions of today's traffic management, as it would enable direct vehicle-to-traffic system interaction, and would allow new possibilities for local, sector and wide area traffic optimization.

EVE foster also the adoption of FEVs in Europe as it a means for assessing CO reductions when different adoption rates of FEVs are considered. The Green Mobility challenge is one of the most important issues within Smart Cities as it aims at providing alternative solutions to fossil fuels' environmental burden. In fact, a crucial problem in nowadays cities and, (more generally), highly urbanized areas, is the always growing level of traffic that deeply affect pollution and quality of life in general of citizens. To face this challenge, the solution that is being foster by the usage of EVE is the electrification of mobility and road transport.

The usage of a Fully Electric Vehicle Traffic Simulator can be also a means to support the municipalities in the application of urban policies that might help the introduction of the FEV to solve several constraints that affect today cities. In particular, the usage of EVE can help City Councils to take decisions based on transport indicators and efficiency ratios and their impact in the city environment. In particular, the support of EVE for the prediction of energy demands and for the optimization of recharging infrastructures planning is very important for Regional or National Public Authorities to assess and evaluate the impact of wide adoption of FEVs in cities.

3. Intelligent Transport Systems Services For FEV

This chapter provides an overview of the issues to be solved for wide adoption of FEV into urban and interurban traffic.

3.1. Efficient Routing/Advanced ADAS

The relatively recent development of electric vehicles (both FEV and hybrids) has also raised some interest in the investigation of optimal routes, specially designed to maximize battery-life and palliate the so-called "range-anxiety".

Some of last-generation FEVs support advanced interfaces and features aiming at increasing the confidence of the driver in his/her vehicle, usually through a pervasive integration with on-board network. For example, the BMW i3 supports a Smartphone app that calculates and graphically shows current vehicle range by reading actual battery level from the CAN bus.

However, at present time, there is no commercial product specifically designed for FEV-oriented, energy-efficient routing and navigation. Until now, this field has been investigated mainly at academic and research level, through a series of studies, ranging from theoretical calculations based on crowdsourcing from serious games (Niesenhaus, 2011) or on theoretical and empirical calculations (http://www.ecogem.eu/).

Among EU-funded research programs, the FP7 EcoGem project (which can be considered as the predecessor of EMERALD) provided probably the most comprehensive results about routing tailored for FEVs. It covered several areas related to EMERALD:

- On-board ADAS equipped with monitoring and machine learning functionality, and targeted at route planning and recharging optimization.
- Enhanced traffic and recharging management platform at the infrastructure side.
- Secure open interfaces to the platform.
- Enhanced data security, user privacy and acceptability.
- Considerable exploitation of existing V2X technologies.

Other European FP7 projects related to FEV navigation (and more generally to energy-efficient routing) are listed below:

eCo-FEV (FP7, 2013-2015) aims at creating an integrated electro-mobility IT platform. The eCo-FEV platform will enable precise EV telematics services and charging management services based on real time information. The project includes the acquisition of routing data and V2X-communication, but it does not include the planning of customized routes based on predictions.

MOVESMART (FP7, 2013-2016) aims at providing time-dependent route planning and renewable personal mobility services using a set of crowd-sourcing tools for collecting real-time information by multimodal travelers.

MOBINCITY (FP7, 2012-2015) aims at the optimization of FEV autonomy range and the increase in energy efficiency thanks to the development of a complete ICT-based integrated system able to interact between driver, vehicle and transport and energy infrastructures, taking advantage of the information provided from these sources in order to optimize both energy charging and discharging processes (trip planning and routing).

eCoMove (FP7, 2010-2013) takes into account the traffic status in the whole network, as well as the co-operative vehicle communications. The project is targeted to a wide variety of users and stakeholders related to traffic, all of the interested in reducing fuel consumption and traffic congestion. Nonetheless, it does not take into account any special needs of the FEV.

ELVIRE (FP7, 2010-2013) project's purpose is to develop an effective system which is able to neutralize the driver's range-anxiety. ELVIRE will address a system that will anticipate and be aware of both users' charging needs and the state of the grid. On-board services will rely on a Driver Assistance System that shall connect to the computers of the grid operators and identify which utility is running the nearest local power plug. An on-board charging and metering device will have to monitor the EV's energy status and compare it against the predicted energy required to reach the destination. These new in-vehicle technologies will grant support to the driver and navigate him safely throughout the E-Infrastructure, toward the most appropriate power plug (http://www.elvire.eu).

3.2. Management of Recharging Points Infrastructure

The management of recharging infrastructure booking for FEVs is a crucial step to ensure optimal exploitation of grid resources and also to guarantee that the power demand coming from the FEVs is appropriately covered in order to reduce the risk of insufficient power supply in the grid. The focus of the research in this field has been concentrated towards the development and deployment of recharging booking services, as well as on providing the driver with a decision support mechanism regarding recharging strategy. They are based on real-time information regarding the availability of charging spots and information about the FEV's status.

Intelligent recharging booking functionalities rely on location-based services built upon GPS technology. At the same time, the vehicle charging strategy has to cope with the necessity of coordinating and scheduling multiple recharging requests with different time constraints and charging amount. In fact, if many FEVs start charging during a short time window and an appropriate distribution of the FEVs is not performed, this may result in an extremely long waiting time. There is therefore the need of providing tools that can help assess energy demand for the grid infrastructure and can support the optimal planning of recharging points' location.

3.3. State of the Art

The Advanced Drivers Assistance Systems (ADASs) support the driver of a vehicle in several tasks related to driving. There are different ways of supporting the driver, depending on which specific feature the system is focused on: in-vehicle navigation system with typically GPS and TMC services for providing up-to-date traffic information, adaptive cruise control (ACC), dynamic radar cruise control (DRCC), lane departure warning, lane change assistance, collision avoidance, intelligent speed adaptation or intelligent speed advice (ISA), night vision, adaptive light control, pedestrian protection system, automatic parking, traffic sign recognition, blind spot detection, driver drowsiness detection, vehicular communication systems, hill descent control, steer-by-wire (SBW), brake by-wire (BBW), pre-collision safety system (CSS), intelligent parking assist (IPA), emergency brake signal, electronic stability control with traction control and electric vehicle warning sounds (used in hybrids and plug-in electric vehicles).

The ADASs that are commercially available at the moment are generic for all kind of vehicles, so in most cases they do not take into account the FEV's special needs.

FEV recharging management are mainly oriented to provide suggestions and to identify recharging strategies aiming at satisfying basic mobility needs (e.g., reachability of selected destination), or extending battery lifetime (e.g., by keeping track of recharge history and by avoiding subsequent –and potentially dangerous– fast recharges).

In general, available solutions are focused on the optimization of recharging scheduling taking into account the grid operators' point of view. The challenge is therefore including drivers' point of view in the optimization process considering not only a single grid operator but several grid operators (with different resources to which different pricing would correspond); moreover other parameters like grid operators recommendation, current location and energy need for the vehicle will also need to be included in the optimization problem.

There are several commercial solutions that are currently available to support the FEVs driver in the process of recharging spot booking. However, no data on the FEVs context and user history is handled when performing the recharging scheduling so that no data such as vehicle's recharging history, current battery level are processed.

Regarding the availability in the market of traffic simulators which take into account the FEVs, some example is already available in the literature. The Electric Vehicle Scenario Simulator (EVeSSi) (Soares 2012) enables the definition of electric vehicles scenarios on distribution networks using a built-in movement engine. The scenarios created with EVeSSi can be used by external tools (e.g., power flow) for specific analysis, for instance grid impacts. The Simulation Platform of the OpEneR project (www.opener-project.org) provides the simulation including management of electric auxiliaries and modeling of driver behavior. However, both of them do not provide a holistic simulation framework where the impact on the electric grid can be directly assessed.

4. EVE Traffic Simulator

The FEV Traffic Simulation Platform plays a key role as a means to validate the long-range route planning and optimization and can be also used to provide basic data for calculating power demand prediction and to provide optimal localization of recharging points in the map.

4.1. Functionalities/features

The main features of the FEV Traffic Simulation Platform are described in the following. First of all EVE provide a means for synthetic traffic scenario generation on the basis of different network topologies and context information (e.g. different FEV types, weather conditions, etc.). In addition, EVE can serve as a validation service to assess the performance of energy efficient route planning technologies with respect to normal route planning and at the same time can provide large scale simulations, to gather insights on the efficiency of the novel optimal route calculation solutions. For this purposes, the EVE simulator has been deployed and used in the EcoGem service and will be further improved along EMERALD project.

Planned improvements regards first of all energy consumption prediction: this functionality will enable the calculation of the estimated energy consumption and, consequently, to predict the power demand needed from the Utility providers. The simulation platform will collect information on past recharge schedules per geographical area. This information will be used to predict the power demand for the available grids: gathered data will be processed per geographical area, taking into account past recharging schedules and past recharging history.

Moreover, EVE will support recharging station planning by optimally locating the recharging points' into the network topology. Starting from the predicted power demand per geographical area (provided by the service above), this service will provide information on where locating the recharging stations, on the basis of the data on historical recharges and calculated predicted power demand.

4.2. Implementation

The FEV Traffic Simulation Platform that will be further developed in EMERALD and ACCUS projects will be an evolution of the traffic simulator developed in the EcoGem project. The developed simulation platform had the ability of handling different vehicle types, especially simulating the behaviour of electric cars, getting detailed information on the simulations and retrieving detailed simulated data.

The EcoGem Simulation Platform suite was designed to be accessed remotely as a web service; therefore also EMERALD/ACCUS simulation framework will be a web service. The EcoGem simulation platform has been deployed thanks to the development of an Adapted Traffic Simulator which was built starting from an open source traffic simulator (Simulator of Urban Mobility, SUMO) that was extended in order to include the FEV models and that was integrated in the simulation suite.

The main introduced extensions were the following. First of all the adaptation of an electric vehicles theoretical model: SUMO introduces the concept of 'vehicle devices', such as an emissions control device or a person device for advanced person interchange, f. e. from private vehicle to bike or bus. An additional 'FEV control device' was created to manage the simulation of common FEV battery measures and common FEV features such as efficiency ratios and weight and torque parameterization, etc… Moreover, the functionality of reading/writing XML extended simulation scenario input/output files that are produced/consumed by the Simulation Web Interface was implemented.

The majority of the Simulation Platform functionalities were developed within an ad-hoc middleware in order to reduce development complexity, isolating critical features and also due to GPL license restrictions that apply for the usage of the SUMO traffic simulator.

5. CONCLUSIONS AND FUTURE WORK

This paper presented a novel Fully Electric Vehicle Traffic Simulator that enables the technological validation and support to decision making procedures when deploying Fully Electric Vehicle Infrastructures and Efficient Cooperative route planning in Smart Cities context. The developed tool is able to simulate the impact of Fully Electric Vehicles into real scenarios and to guide policy makers into the decisions for the planning of recharging infrastructures as well as measuring the impact in energy demand that the wide adoption of FEVs would have in the urban areas. The EVE simulator which was developed during the EcoGem project will be further improved during next year thanks to the activities of the ACCUS and EMERALD.

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