Moby.Cockpit Project for EV Seamless Integration in the Cooperative Transport Infrastructure

Joao Ferreira, Vitor Monteiro, Joao L. Afonso

Abstract—Electric Vehicles (EV) are being introduced in the market, however the reduced energy storage capacity of their batteries and the lack of a high density charging infrastructure, limits their autonomy range. In order to overcome this limitation, we propose the development of a new solution for EV drivers that enables to travel longer distances. This is achieved by integrating some components of the cooperative transport infrastructure, as EV battery charging systems and public transports systems, and by increasing the driving autonomy through energy consumption reduction, achieved by driving efficiency increase. The integration with the charging infrastructure allows planning the journey of the driver, considering the position of charging points, and booking a charging point for a specific time period in order to perform the battery charging. Therefore, the distance that the driver can drive comfortably, without fearing running out of battery, is increased. The integration of the EV with public transports systems allows extending the travel distance beyond the EV drive autonomy, given by the storing capacity of vehicle's battery. The supplying of information on availability, schedule and price of public transports allows planning the journey of the driver, using the EV and public transportation in a complementary way, through functions like car parking booking (and charging) and ticket buying.

Keywords—Decision Systems, Data Warehouse, Data Mining, Electric Vehicle, Energy Efficiency, Information Retrieval, Knowledge Discovery, Public Transportation, Range Autonomy.

I. Introduction

Mobi.Cockpit is an integration project, which gathers the developments achieved in several technical areas into an unique system. The main technological areas to be considered are automotive navigation support, public transport information integration, and Electric Vehicle (EV) energy consumption and management.

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The 21st century has emerged in an era of heightened connectivity. Most people use cell phones at all the time and most of those cell phones operate as web enabled devices and search engines. The in-car infotainment industry has being developed more quickly in the past five years. Thus, as consumers become more and more interested in making their cars as connected as they, this industry is used to integrate their phones and laptops in the vehicles.

The automotive navigation support to the driver is based mainly on the Global Positioning System (GPS). This system provides the position of a receiver, which is used by upgraded systems to provide additional information such as speed and further integration with maps and geo-referenced information to provide the driver with information concerning time to destination. However the integration of these systems with the traffic information is one of the main issues of current R&D in this field. In fact the potential of the integration of real time traffic information with the navigation system brings significant benefits to the final user, both in terms of route planning and driving safety. In this field, several projects have been developed integrating the navigation system, car sensor and infra-structure information to create systems that can supply the driver with information for route planning and driving awareness. Additionally, the EU ITS Directive 2010 [1] requires member states to deliver a number of systems as per the ITS Action Plan. These include provision of Multi Modal Traveler Information Systems by 2015. For the Mobi.Cockpit project the value of this information is explored in the context of EV trips.

II. Mobi.Cockpit Project Overview

The Mobi.Cockpit project develops a solution that supports the driver with the appropriate and relevant information to decide and plan his journey using an EV. Therefore, are reduced the constraints related with the EV autonomy and the driver can perform his journey with reduced anxiety about vehicle range. The proposed solution in the Mobi.Cockpit project (Figure 1) integrates an information system that combines the data from the vehicle, the data from the public transportation infrastructure and the data from the EV battery charging infrastructure. This information is used to interact with the EV driver through an infotainment system on-board of the vehicle or through a mobile device that can be carried with the driver in or out of the vehicle. The on-board system, the handheld device and the web application can all supply the driver with the required real time information to plan an EV-multi-modal journey and to support efficient driving, enabling travel longer distances, with less anxiety.

This project is located in the intersection of the EV integration problems (e.g., new charging infrastructures are being prepared and several problems have been raised due to limited range autonomy and the long time of the battery charging process), with the new paradigm of smart cities where a cooperative approach is established among different transportation sources. Information and Communication Technologies (ICT), with mobile communications and mobile information systems, plays an important role in this process, mainly to the integration and real time information access. The results bring a rise in drivers' information needs, because information forms a key part of the driver decision process. The success of the EV penetration in the market is in part due to this information availability at the drivers' side.

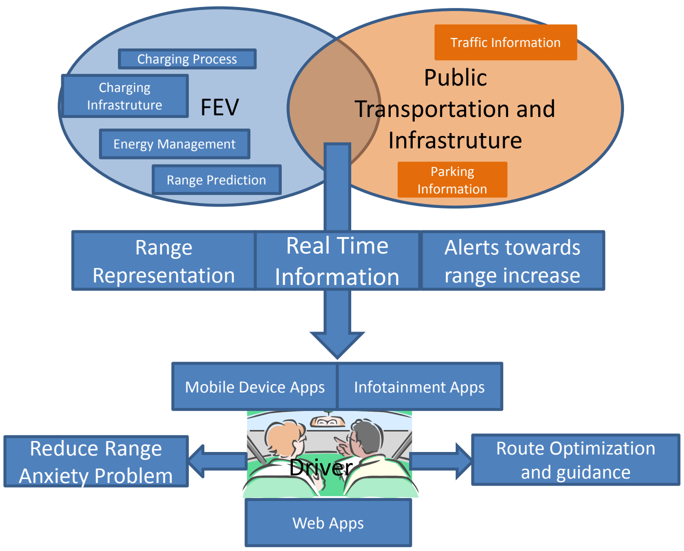

Fig. 1 Main structure of the Mobi.Cockpit project.

The main objectives to be attained with this R&D project are: (1) Cooperative integration of the transportation infrastructure, by providing the driver with a collaborative holistic approach of different public transportation infrastructure sources, that can be combined with real traffic information, parking places and charging slots and current driver position, to support the driver decision making process; (2) Real time interaction with Public Charging Infrastructure (PCI), by providing real time information about PCI location, availability and commercial conditions, and possibility to perform charging slots reservation. Integrating all of this information and the range prediction information, the charging process could be oriented to a minimum level that allows the driver to reach destination; and (3) Perform route optimization considering other several factors on route calculation that contributes for the improvement of the time and energy consumption efficiency of the route. Factors such as traffic, route slope, speed limits and weather conditions can contribute to plan a route with less energy and power demanding (routes that demand higher power for traction in some parts, can cause a reduction in the whole vehicle efficiency), and with less time needed to perform this route. These factors also contribute to integrating information from the PCI and the public transport infrastructure aiming to increase the EV autonomy through a more intelligent driving planning and mode.

Mobi.Cockpit project explores new ways of using smart phones and infotainment systems for gathering data and providing user-centric navigation services that supports EV energy management, range prediction [2] and representation, and cooperative approach with public transportation infrastructure. The envisioned technologies are integrated in real-life apps that can be downloaded onto the device and offer an easy-to-use platform that interacts with the proposed mobility cloud to share context data and obtain sustainable routes and guidance.

A. Problems to Solve

This research work deals with the development of a real time information system to assist EV drivers with relevant information. The following issues are addressed:

- The problem of EV battery charging using the MOBI.E system (Portuguese electric mobility charging infrastructure and management system).
- Charging station locations and interaction (reservation of charging slots or information on energy transactions) are available through the Mobi.Cockpit drivers interface (e.g., mobile device, infotainment system or web page).
- Minimization of the driver range anxiety problem by: (1) An accurate EV range prediction based on past driver behavior, batteries State-of-Charge (SoC) and external parameters like road characteristics, traffic conditions and weather; (2) Range representation on a map taking into account the current driver position with an uncertainty associated with driver behavior; and (3) Guidance and reservation of PCI charging slots.
- Integration of the EV in the cooperative transport infrastructure by the different sources of transport data integration and the best route guidance, taking into consideration different transportation options combined with traffic information, using the main outputs and experience of ITTIS and START Seamless Travel across the Atlantic Regions using sustainable Transport projects [3], plus experience from national journey planners (UK). This integrated view can be combined with the EV battery charging, where the driver can park the EV on a PCI, and use public transportation to reach a city destination, while the EV performs a slow charging. This is in line with new realities on sustainable mobility in smart cities that increases the need of information systems to support a diversity of options and processes.
- Route optimization and driver education behavior towards energy saving. The reduction of energy consumption may be reached using an improved route planning selecting routes with lower climbing rates, and reducing the power demand from the batteries. Combining this route planning with weather conditions, especially extreme temperatures, a

reduced power demand may be attained if less power is required at the same time, both to control the inside vehicle temperature and to the vehicle traction. At the same time, selecting a route with less traffic congestion or with less traffic lights, reduces the amount of braking effort of the vehicle, reduces the energy lost during braking (that is significant even if regenerative braking is available), and reduces the amount of energy spent on acceleration. To implement some of these measures, a new driving method is required, making the driver more aware of the energy consumption and how the driving style and habits has impact on the energy consumption, proposing new attitudes and behavior for the EV driver.

Due to the diversity of the topics involved, the integration with the information system from the charging infrastructure is provided by the MOBI.E system [4] and by the MOBI.Europe project [5]. On public transportation cooperation MOBI.Cockpit project uses real time information on mobile device or infotainment system to give to the driver an integrated view (road information together with transportation options and parking places) related with how the driver can reach the desirable destination.

Once the centralization of this information is performed, the MOBI.Cockpit project is able to provide driver useful information related with: (1) Route optimization and guidance towards desirable destination, taking into account range limitations, traffic and road conditions, using suggestions of public transportation or car and bike sharing services; (2) Shows a personalized range estimation and representation to check if the drivers can reach the destination with or without battery re-charging or driver optimization; and (3) the MOBI.Cockpit project is able to generate to the driver alerts towards energy saving. In this process real time information is crucial and it must be extracted from the EV. Here a main barrier may arise once each vehicle model or each Original Equipment Manufacturer (OEM) does not release the information for this data acquisition process. Considering this, an open source EV under development at CEIIA [6], may prove the benefits from that, by creating synergies with other data systems and create useful information in real time for the EV driver. CEIIA has already developed two complete EVs, one on production at Norway, Pure Mobility Buddy09 and a second vehicle developed with CTAG [7] on the MOBI-ONE cross-border project, named the *alfa* prototype, which is used as a test platform for new technologies and solutions to be used on EVs.

III. Main Mobi.Cockpit Modules

Figure 2 shows the main system components developed towards the goal of giving real time information relevant to the driver, increasing the driving range, reducing the range anxiety, and allowing a cooperative approach with public transportation. This project develops the hardware and software needed to implement all of these functionalities on a mobile device or an infotainment system in an EV, which works as the interface with the driver and communicates with the EV to get information on the vehicle parameters. Several interfaces are developed for data acquisition (traffic, weather, public transportation operators, charging infrastructure and geographical position) as well as algorithms for route calculation, range prediction, infrastructure interaction and vehicle control. The study of the driver behavior and strategies for creating and adopting more energy efficient driving habits towards the definition of strategies that can be adopted by the driver or can be implemented as automated actions, contributing to the energy consumption reduction and driving safety.

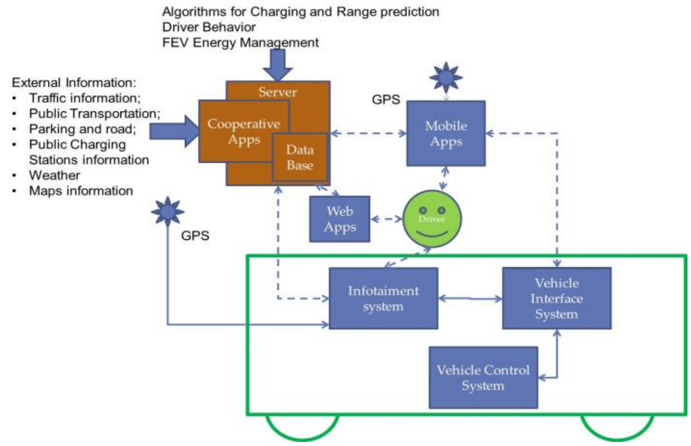

Fig. 2 Main Mobi.Cockpit mobile application components.

The Mobi.Cockpit mobile application is a single application, deployed on a mobile platform (iOS or Android), run the extended range navigation, interaction with public transportation (Cooperative Apps) and EV charge management modules. User's mobile application can be used everywhere. It possesses all the same functions as the head unit, e.g., the speed meter or the navigation function. With it the users have flexible functions offered in different locations, not only in the EV (e.g., the EV user is able to follow the status of the battery charging at home). For the computation of the trip planning and route optimization the following options are available: (1) The cloud services alone is using all the data and computing the results. The results are then sent and displayed on user's smart phone through the Mobile App or sent and displayed on the Car's Head Unit; (2) The smart phone and (3) The Car's Head Unit.

The Geographic Information Server (GIS) server is responsible for the data representation of the 3D topography, the vertex/node abstraction. From this the local street grade can be computed.

The ENV (Environment Server) server is responsible for the weather data like current temperature, wind, but also responsible for the computing and delivering of the battery charge cycles and the driving style. The battery charge cycles and driving style data are deduced using data coming directly from the car, like battery SoC, speed and positive and negative acceleration data.

The Mobi.Cockpit infotainment system, as a mobile device application, integrates the Extended Range Navigation application, Extended Range Navigation and the EV Charge Management.

The Vehicle Control System creates an interface between the physical layer (CAN-Bus) and client devices. Parameters such as vehicle speed, battery autonomy (among others parameters), shall be delivered to upper layers (mobile device, telematics or navigation system). By doing that, we increase the range of options for the EV, since these parameters gives the driver a better control of the entire system. That means more efficiency and comfort.

The development of the Vehicle Interface System (VIS) includes the development/selection of a basic electronic unit that can accommodate the different interfaces required for this system (CAN-Bus, Bluethooth, 3G, Wifi). The firmware developed implements the API specified in the Vehicle-to-Infrastructure (V2I) communications and enables ease connectivity between off-board applications and the vehicle. Taking into account all the necessary data transfer between the vehicle and the cooperative infrastructure, the complexity of inner-vehicle architecture must be abstract from the high-level applications.

The Cooperative Transportation Infrastructure specifies on the server side application responsible to integrate multiple sources of traffic and transportation information that is used by the mobile device, infotainment and web applications developed for Mobi.Cockpit project. In this module we integrate and exchange information of public transportation (e.g., stations/stops, routes and schedules), parking places (with or without PCI) and traffic information. This task has the mission of making a mobile device application with a best path algorithm associated to achieve a concept proof of merging electric mobility and sustainable mobility processes. This module is based on a central information server to store or query transportation data taken from different sources, varying by the test site. These include international (e.g., Google Transit), national (e.g., Transport Direct), or local sources, informed by experience and standards defined in the START [3], ITISS [7] and WISETRIP [8] projects. We specify a method to join public transportation data with traffic information and parking place location/status to achieve a wide range of transportation options. To this centralized information we add specifications for real time traffic information and decision-aids on the best option, based on pre-defined criteria (like fastest option, cheapest and also guidance). Most of this traffic information is acquired via existing web services. Our central system allows the interrogation of multiple sources of information through a single interface. The inputs and outputs are reflected by a single data model.

The existence of a common data model aids the software applications with the otherwise difficult task of dealing with various technologies and their different relational schemas. As a result, different transportation systems can be accessed by the end user. This integration is described in [9], through a domain ontology definition for public transportation, where local public transportation operator data base are mapped.

The Extended Range Navigation module is to specify the extended range navigation application. This application, which is used in any of the different platforms of Mobi.Cockpit project (mobile, infotainment and web), takes advantage of information of the EV consumption and the battery life combined with algorithms develop for personalized range prediction, described in [10]. At computing the shortest and the fastest route the best economic routing strategy is to use a mixture of both. For the EV it may be important to optimize the route by energy consumption.

Extended range navigation specification addresses mainly two different tasks: (1) Extended range prediction; and (2) Extended navigation. Both tasks are combined in order to get the user of an EV as fast as possible and most reliably to his desired destination. The optimal combination between the fastest and the energy consumption optimized navigation strategy is called Energy Navigation System (ENS). For the limited range of an EV it is highly important to optimize the route by minimizing the energy consumption. A mixture between the fastest and the most economic route is implemented (with special focus to energy consumption, which depends strongly on the environment). This module provides the drivers with a new navigation experience more suitable for the EV. This experience takes into account the necessity of suggesting consumption efficient routes and/or routes that takes into account the charging need for the specific EV.

For the computation of the trip planning and route optimization the following options shall be applicable: (1) The cloud services (consisting of GIS, ENV, and Environment Server) residing on the Integration Platform uses all the data and computes all the results. The results are then sent and displayed on user's smart phone through the Mobile App or sent and displayed on the Car's Head Unit through the Infotainment System; (2) The smart phone; and (3) The Infotainment System's Head Unit. As result, the extended Range Navigation develops an approach on how to best match the data coming from the EV and the cloud services residing on the Integration Platform, on how to compute them, and finally, displays the best route and optimized range to the user, either on the smart phone or on the Head Unit.

On the context of electric mobility, the management of each driver's EV battery charging needs becomes an important aspect. With the EV Charging Management Module it is delivered additional navigation features from a cloud service, giving overview of available PCI and/or EV parks nearby. If a user is driving an EV and realizes that the battery of the vehicle is getting out of charge, he can ask the Mobile App for another EV or for a nearby PCI. Then the Mobi.Cockpit system can display on the driver's smart phone the nearest available PCI or EV, and the optimized way to get there.

The cloud service gets the needed information from municipal authorities or specialized third parties. The definition of charge requirements for each time the EV is "plugged-in", together with management of personal balance charging (historic data, consumptions, etc…) are some of the functionalities to be provided by this application, contributing to the overall goal of providing the driver with more confidence in its EV driving experience. The services to be published provides the proper interface to the EV charging network as well as providing an interface to the smart grids that enables the future leverage of the results of this project with projects aiming the development of systems for the smart cities.

IV. CONCLUSIONS

This research project, performed along the last 4 years, was based on one PhD thesis and nine MSc dissertations, and results from the collaboration between research institutes and the Portuguese development center (CEIIA). The following objectives were achieved through the various results expected by the project, which can be categorized as:

1 – Minimization of losses and improvement of the energy storage system: Creation of systems/strategies that improve the control of the air temperature inside the EV; reduction of the energy consumption on the air conditioning (e.g., if air conditioned is turned off during EV acceleration it reduces the peak power extracted from the batteries, increasing its lifetime); generation of warnings for driver actions towards energy consumption reduction (e.g., close windows at high speed, cheek tire pressure, etc).

2 – Route Planning: Consideration of the climbing effort on route planning, since this will increase energy consumption; consideration of traffic and possible driving speed and vehicle drag coefficient to plan the more energy efficient route; consideration of environment conditions (and controlling of the air temperature inside the EV) to plan routes with less power demand from the battery and reduced energy consumption;

3 – Battery Charging Infrastructure Integration: Finding of best charging point location and availability; booking of charging point and parking space; selection of charging point with best energy and parking costs, balancing it with different charging points possibilities.

4 – Transportation Infrastructure - This integration allows a personal range extension, using complementary or alternative efficient public transport planning: Book intermodal parking place; planning of complementary route using public transports; ticket booking of public transportation (train, bus, metro, etc).

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