EV-Cockpit – Mobile Personal Travel Assistance for Electric Vehicles

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Abstract

This paper describes the concept and a prototype proposal for a mobile information system to support the mobility process in cities, such as it gives recommendations to drivers about Public Transportation, Car or Bike sharing systems. Electric Vehicles (EVs) integration will contribute to the reduction of usage of private cars in the cities and also to decrease the CO_2 emissions. EVs will play an important role in the integration of renewable energy sources (intermittent sources) in the open Electrical Market, and the complexity of the charging process will be a great opportunity for the development of systems oriented to mobile devices and to social networks. The main objective of this proposal is the creation of a platform based on successful approaches developed in the computer science area, like recommender systems, cooperative systems and social networks, to help the creation and establishment of smart cities.

1 Introduction

Automobile plays an important role in transportation and new challenges appears with the introduction of the Electric Vehicle (EV) in 2010: the so-called city electric vehicles, that are, EVs with a autonomy of less than 160 km. Drivers of such EVs will have to cope with a new problem: EV charging takes time and they need to deal with limited electric range - this problem is called in the literature the “range anxiety” [1]. The success of EV in part is going to depend on how comfortable people are so that they can get where they want to go, without running out of charge, and without having to go through some process that will take them a long time and impact their ability to use the vehicle. So, taking out in real time EV information, such as SOC (State of Charge), energy transactions and others vehicles events plays an important role. This information, taking into account recent progress in mobile devices, geographic information system and communication processes, can bring added value to drivers.

EV-Cockpit is a mobile system for EVs drivers that bring the ‘right’ information for them. Since the realities of smart grids, open energy market, and smart cities with increasing mobility sustainability, the proposed system integrates a diversity of functionalities, illustrated in Figure 1:

- **ICT Supported Functionalities**: The EV-Cockpit System receives the geographical positioning information of the EV current position and the features that enable the calculation of distances between two points. Main ICT (Information and Communication Technologies) contributions are the GPS devices, mobile devices and wireless communication for user’s information access from anywhere, and also the corresponding geographic information system.

- **Mobility Sustainability Functions** that involves the following: (1) Car sharing and Bike sharing, systems to support mobility functions in ‘smart’ cities [2, 3]. (2) Integration of Public transportation information to create a route planner based on public transportation. (3) Information on Points of Interest: Information about points of interest is preloaded on the system and is used for direct consultation by the driver, who can perform a quick search for points of interest near the present location. The information is also used in the recommendation of charging points, for all that remain at a distance, for example less than 5 km, will be marked as being “near the point of interest” [5]. (4) Parking places available and remote parking slots reservation. (5) Route planer, based on the integration from different data sources, such as multi-modal public transportation systems, car and bike sharing, or car pooling [3].

- **Energy Market Functions**: (1) Aggregator for energy market participation. (2) Collaborative broker for Distributed Energy Resources (DER) [6]. (3) Account system for electricity transitions with price control. The EV-Cockpit system receives the discounted value of the price of energy from the energy market, consulting it regularly. The only information received is the fare in the current format €/kWh, or euro value per thousand watt hours consumed. The energy market information is used to control the battery system during periods of loading. If the price of energy rises above a configurable threshold, the EV-Cockpit system sends a command to the battery system to stop charging. If the price falls back to an acceptable level, an alert is sent to start charging again.

- **Charging Functions** that involves the following: (1) Range anxiety utility functions, such as: display of SOC, remaining kms for next charging, driver profile, looking for nearest charging station (with guidance and charging spot reservation). (2) Remote charging control interactions, by the possibility of remote commands. (3) Tracking system. (4) Consumption simulation for smart charging strategies taking into account distribution limitations and establishing of a smart charging strategy. (5) Micro grid integration.

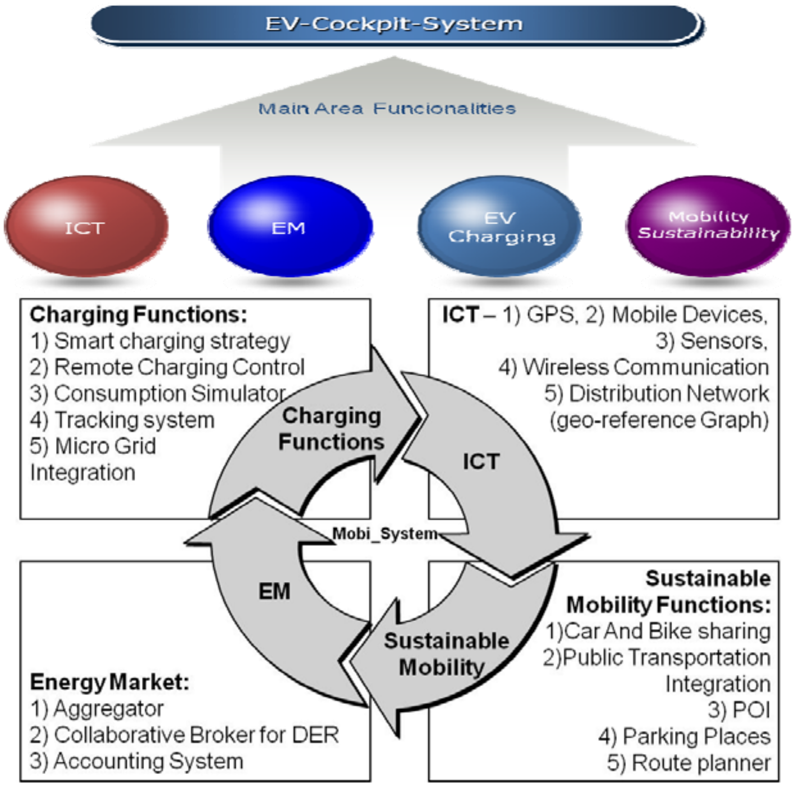

Fig. 1. EV-Cockpit main functionalities and purposes

2 Mobility Sustainability and Energy Market Functions

Our approach considers a central system with the aim of creating conditions and incentives for drivers to use less their own car, by giving guidance and suggestions for others transportation systems, like public transportation, bike sharing, car sharing or even car pooling [2]. EV-Cockpit system works also based on real traffic information, supporting decision for the best options taking into account pre-defined criteria (e.g., fastest option, cheapest option, option with less CO_2 emissions), as Figure 2 suggests.

EV-Cockpit is a system [3] integrated in the START European project [4], that allows the citizens to obtain information (e.g., timetables, routes and prices) on the various modes of transport (e.g. bus, tram, metro, train, ferry) available in a particular region or city, focusing on the integrated use of soft transport (e.g. electric vehicle, bicycle) and occupation of waiting time (eg, visiting points of interest), and is based on a local domain ontology for public transportation data integration and others systems, like bike and car sharing, or even car pooling. The idea is to pass public transportation possible itineraries to a graph, where the arch length is defined by the time that takes to go from one node arch to the other. The same procedure is applied for car sharing, car pooling and bike sharing systems. If we have all this information in a graph, we can use the Best Path algorithm (a Dijkstra algorithm implementation) [3], where the arch weight that connects to adjacent nodes can be constructed from a diversity of options, like related time, price and $C0_2$ emissions.

The main contributions of this work are the following: (1) a domain ontology definition for Public Transportation; (2) a data integration of Public Transportation in European environment; (3) a functional prototype to query and give advice regarding the best path from a point A to point B using Public Transportation facilities; (4) an implementation in RDF/RDFS (Resource Description Framework Schema) that allows the use of the emergent query language SPARQL; and (5) an implementation of the best path's Dijkstra algorithm and a diversity of public transportation information sources, (details for this can be found in [3, 7]).

Regarding energy market functions, because of their batteries, EVs present an interesting potential as a storage facility. However, the storage capability of the EV batteries is small on the grid scale, and consequently their individual power output cannot have any impact on the power system. For the EVs to be able to play a role when interconnected to the grid, they need to be grouped into communities. Once aggregated, they are able to provide different kinds of services, either as a controllable load or as a generation/storage device. However, the EVs may not be always plugged into the grid and their schedules are very uncertain. We have developed a conceptual V2G (Vehicle to Grid) aggregation platform to solve this aggregation problem, based on a collaborative approach with a credit mechanism to measure user participation and to divide energy market participation revenue [8]. Also, other aspect of this problem is the integration with micro-generation and the problem of handling the distribution energy sources [7]. In this process is important to determine the EV driver behavior through user profile with information like time of trip, distance, daily hours connected to the grid, or minimum energy stored. For that we have developed a tracking system to work offline in a mobile device with GPS [9, 10].

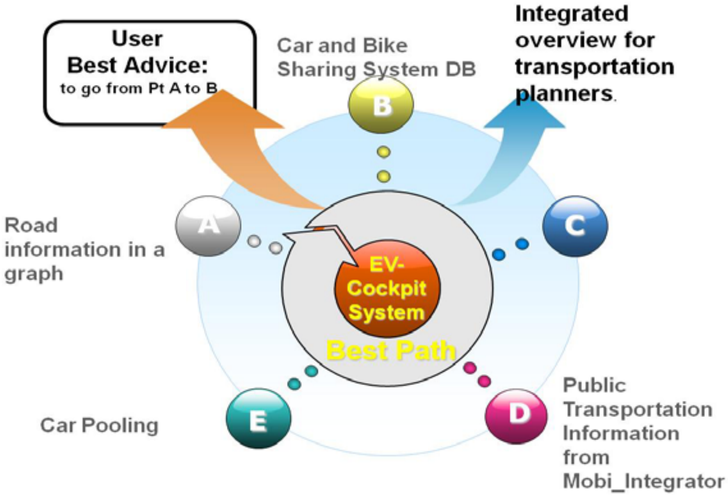

Fig. 2. EV-Cockpit System transportation related system

3 Charging Functions and Users Applications

Main charging functionalities are related with the charging process and with the dealing of the range anxiety problem, which are illustrated in Figure 3. One major issue in this problem is the vehicle external information access and sharing among the different stakeholders. Vehicle manufactures traditional blocks most vehicle external information access, but community will benefit from a collaborative information sharing. There is a progressive tendency for the creation of laws to oblige OEM (Original Equipment Manufacturers) to share vehicle information, but we will not discuss this here. But once this issue is solved (that information should be shared), there are two approaches: (1) OEM starts this business and transmits related information to nearby mobile devices through Bluetooth; or (2) through the usage of a standard communication interface (e.g., CAN-Bus interface) the relevant information is extracted in real time. We have explored this second approach to develop an OBU (On Board Unit). We have performed some work on this second approach, based on a microcontroller that integrates CAN, Bluetooth, GSM/GPRS (global system for mobile communications / general packet radio service) and GPS (global positioning system). The implementation of CAN protocol allows to receive real time data from EV. With the available OBU wireless communications interfaces, it will be possible to report both locally and remotely the data being received from the EV through Bluetooth and or GSM/GPRS technologies, respectively. Moreover, Bluetooth allows the OBU integration with mobile equipment, such as a mobile/smart phone. Additionally, and by having knowledge of the EV current coordinates (GPS receiver), the OBU will be able to make the best decisions through the platform. GPRS will allow the development and implementation of the OBU update over the air, increasing the easiness with which software updates are made.

The CAN or CAN-bus is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other within a vehicle without a host computer. Thus, the idea is to develop ways of taking vehicle relevant information to computer systems (mainly mobile devices). This allows feeding our developed application with real data from EV. From this case study, since there are standards, the idea is to create an open tool that can work in all vehicles with CAN-bus. User information access is mainly performed by a desktop application (V2G Smart System) or by a Mobile Application.

The main functionalities of the V2G Smart System web application are : (1) Registration: registration page for new users; (2) Password Recover: form for password recovery; (3) Login: home page of the application - the user is redirected to this page after login; (4) Profile Creation: page created for user profile by entering information on the EV; (5) Personalized Charge Profile: page load profiling, through the introduction of information regarding the date / time of travel, number of km the driver intends to accomplish, and minimum SOC allowed for the EV batteries; (6) Statistics: home energy consumptions, weekly, monthly and annual energy expenses, price variation of electricity, charging periods, etc. The present application on the server is subdivided into five main modules: (1) Interpreter of

Downloaded Files - this module will be responsible for reading and interpreting the files loading, giving the system a layer of abstraction over the file format of text issued by the loading system; (2) Smart Grid Interface - this module will be responsible for the interaction with the electrical network, i.e., it controls the flow of energy from or to the electrical network, with the objectives of helping network stability, and also, managing information on the variation of electricity prices, to optimize the profits obtained with the selling of energy to the electrical network; (3) User Manager - module responsible for registering the users and their EVs, allowing the recording and editing of users data, as well as the removal of users (if defined rules are not accomplished by specific users) - this module is also responsible for verification of user identity and ownership of registered vehicles (through the transmission of data received from the user to the authorities), and for performing regular cleaning from the database of users categorized as "spam"; (4) Manager Profiles - a user can set one or more load profiles for each of the vehicles registered by him. A common practice is, for example, the definition of profiles and needs of different charging to be carried out during the week (weekdays) over the weekend; and (5) Manager Central - interacting with various modules mentioned above, and managing the distribution of system information (from other modules and database). A Central Information Repository will store EV related information, namely: EV drivers profile, electricity transactions of EV, electricity prices, and other EV related information. Details of this system can be found at [8, 9].

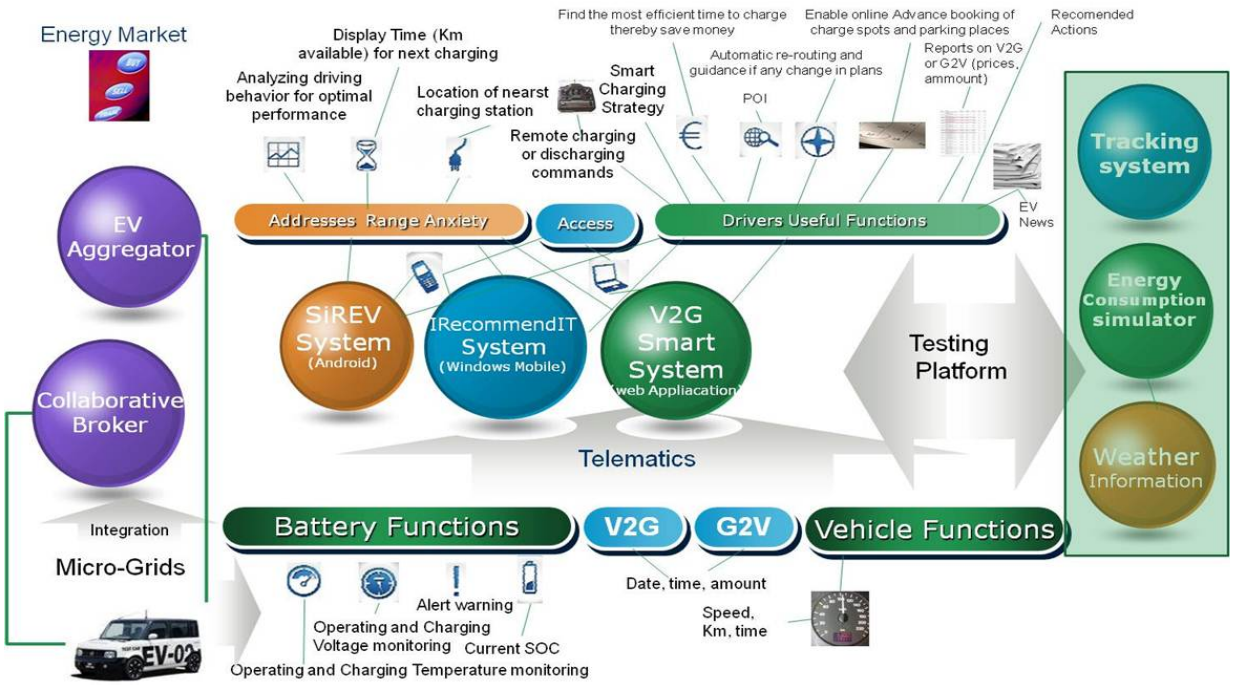

Fig. 3. EV-Cockpit functionalities

The Mobile Application, called EV-Cockpit-Mobile application is used by vehicle drivers to interact and take useful information from the EV itself, but also from charging devices, the Energy Market and the central information server. Due to the diversity of mobile operator systems, this application is developed on top of Android and Windows Mobile platforms.

The driver of the EV can use the EV-Cockpit-Mobile application to: (1) get directions; (2) locate and load charge spots data, reserve slots; (3) get recommendations on his journey with great information needs, as local battery charging, whose constraints are known involving the loading time and their autonomy, local information satisfaction, public transport information in case of failure, etc; (4) get points of interest; (5) define smart charging strategy; and (6) define parameters related to electric market participation (e.g., selling, buying and profit maximization).

The key functional requisites for the EV-Cockpit-Mobile application, illustrated in Figure 3, are the following: Firstly, a process to manage charge/discharge, where the charger or discharger device should receive relatively simple commands such as: charge the battery, wait for further instructions, return energy to the electrical grid, and archive transactions for further analyses. Secondly, the driver mobile device with GPS should track the EV movements in an offline mode (avoiding user charges of GPRS connection). Thirdly, guidance for charging stations, their location, and the reservation of charging spots. Fourthly, the user should establish a profile (stored on user's PC) where he defines his habits (e.g., number and time of travels per week, travel time and distance, weekend habits), and also the minimum SOC level (that allows to drive for the minimum distance). Fifthly, energy market functions, such as to obtain the price information to sell energy. Sixthly, a tracking application should be installed on the mobile device and configured to work in offline mode (to avoid charging expenses). A prototype for Android [5] and Windows Mobile [10] operating systems have been developed.

Charging Platform – IV2G System: It was developed a charging device with a mobile device, in order to perform remote commands and to establish a smart charging strategy, taking into account energy price and power limitation. In typical electric vehicles, when it is necessary to charge the batteries, the energy comes from the electrical grid to the batteries in unidirectional mode, without any control protocol given by the electrical grid. For more details, please see [10].

Simulation of Home Consumption and Finding of Smart Charging Strategy: An agent-based electricity consumption simulator was developed [9, 11] that allows determining the best EV charging process taking into account home and distribution power limitation. It was made a study for different types of residential consumptions with the goal to analyze the introduction of the electric vehicle. It was taken into account the different profiles of families (with different power consumptions and traveled distances), assuming one vehicle per family, and determining the most appropriate forms to charging the EV. Then, it was determined the time of day when there is a larger amount of energy to be used, and consequently, compiling these values of consumption per hour it was found the ideal intervals along the days for EV charging. Also, this platform can be used for the simulation of real testing environments of EV charging, adapted to different countries specificities. Also electric distribution companies can use this tool for future planning, simulation and decision support. Consequently, this information can be used to determine the capability of the actual electric-distribution network for supply energy to the final consumers, and also for charging the EVs banks of batteries, which can occur simultaneously. With this tool we are able to determine a Smart Charging System in order to achieve the goals as identified in Figure 4, i.e., taking into account home consumption and electrical network power distribution limitations, the proposed system identifies a smart charging strategy.

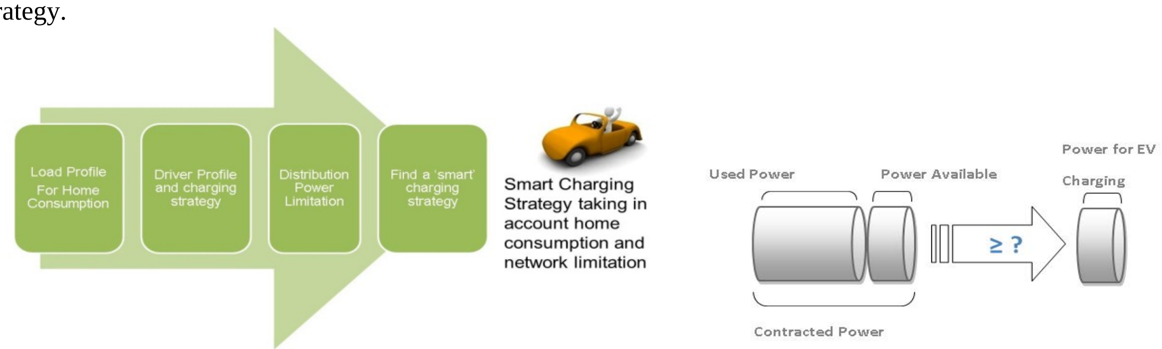

Fig. 4. Smart Charging approach and goals

4 Conclusion

The main goal of this work is to bring ICT and Information System approaches to this upcoming growing area of sustainable mobility process in smart cities, with the introduction of EV and Energy Market participation. All proposed system modules are oriented in a way that mobile devices should be part of drivers' mobility process.

In EV charging and discharging processes, a management system is created with a smart charging strategy taking into account distribution and consumer power constraints. Since there is no real environment for testing purposes, a simulation tool based on agents was developed. Based on this tool and taking in consideration real information (user's surveys and information taken from tracking system) a home consumption analysis was a performed based on agent using a stochastic process. Taking into account the limitations of the distribution network and the user's power contracts, a smart charging strategy was identified (basically this is an indication of maximum power through the time that the charging process can use). In our opinion more complexity can be introduced on this tool, such as microgeneration and discharging process. The geo-reference in a graph, the electrical distribution network and a visualization tool are also proposals, which could help the planning of new distribution infrastructures, and the identification of regions of power constraints.

Considering the Energy Market participation, the main proposal is a conceptual system to create and manage the EV community, with a credit-based approach which is an innovative proposal of this work, together with the collaborative broker for Distributed Energy Resources (DER). In our view, using this credit-base system, together with rankings, the users would profit from an open and healthy competitive environment. Also, in the future, to increase the market share of EVs, there will be a need for these types of systems in order to explore the potential of the energy market for these kinds of vehicles. Also, renewable energy sources integration and microgeneration can benefit from a community coordination action, where users capture renewable energy produced in excess at lower prices at local generation, and also avoiding transportation loses.

In transportation, a diversity of systems to reduce usage of own vehicles is created, reusing pieces of software components, and with approaches created for charging process and Energy Market participation (credit mechanisms, charging spots reservation). The main contribution is the public transportation data integration and the diversity of systems (Car sharing, Bike sharing, Car pooling) available to the users through a single interface: the EV-Cockpit system. This holistic view is important for EV industry in general, but also for end-users, for governments and for public operators, because it gives an integrated overview, where it is easy to identify the challenges and the opportunities of this area.

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