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## MOBILITY 2.0: CO-OPERATIVE ITS SYSTEMS FOR ENHANCED PERSONAL ELECTROMOBILITY

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### Abstract

Mobility2.0 is an ITS project aiming at developing and testing an in-vehicle commuting assistant for FEV mobility, resulting in more reliable and energy-efficient electro-mobility. In order to achieve a maximum impact, Mobility2.0 takes an integrated approach of addressing the main bottlenecks of urban FEV mobility: ‘range anxiety’ related to the limited FEV range, scarcity of parking spaces with public recharging spots and the congestion of urban roads. Our integrated approach means that the application developed by Mobility2.0 will utilize co-operative systems, through communication with transport/traffic city control systems and interaction with the charging infrastructure, to simultaneously consider these bottlenecks, so that such an optimization can be achieved which still guarantees reliable transportation for each FEV owner. The Mobility 2.0 envisioned application acts as a service platform that helps drivers to plan their trip and simultaneously manage the charge of their FEV through their personal nomadic device. This can be achieved by using real time information about the FEV parameters (e.g. vehicle dynamics and energy stored in the batteries), combined with external parameters (e.g. conditions of road traffic, public transport schedules, state of the grid) and learned driver profiles in order to both determine the range autonomy accurately but also provide a multi-modal commute trip recommendation to the FEV user.

This paper provides an overview of the project’s main objectives and the methodology to be used to achieve them.

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# 1 Introduction

In the new challenge-facing Europe the use of electric vehicles is highly desirable for multiple reasons, such as better overall energy-efficiency, CO<sub>2</sub> emission reduction, clean air and better utilisation of renewable energy sources. However, there are still several issues that act as bottlenecks and need to be addressed before a mass-deployment of FEVs can be achievable:

- Limited FEV range, which may lead to a ‘range anxiety’ of drivers in the absence of a procedure that ensures that FEV owners comfortably reach their destination in any circumstance; Moreover, lack of range management systems able to cope with different battery management systems and different driver behaviours.
- Limited availability of parking spaces with public recharging facilities.
- Potential dependency of actual FEV range on grid capacity;
- Scarcity of urban road space leading to general traffic congestions. This can be alleviated by at least a partial modal shift to public transport, as long as the resulting transition is a smooth one.

A suitable traffic management system for FEVs must take each of the above bottlenecks simultaneously into account, in order to achieve a journey optimisation that is acceptable and favourable for all drivers. Such an integrated approach necessitates the use of co-operative systems to coordinate the vehicles and the infrastructure. At the same time, the energy efficiency optimisation over the aggregate FEV fleet is an important objective. Since the bulk of automotive transportation consists of daily commutes to the office and back, Mobility2.0 shall focus on this scenario.

The contribution of this paper is twofold. It (1) analyses the role modern ICT can play in the acceptance of FEVs by providing comprehensive commuting assistance to FEV owners, and (2) provides a high-level architecture of a system for such commuting assistance, utilizing the high penetration of Internet-connected smartphones.

The rest of this paper is organized as follows: Section 2 gives a comprehensive overview of Mobility 2.0 application objectives and research areas. Then, Section 3 analyzes the information flow inside the Mobility 2.0 system and presents the preliminary outcome of the specification and architecture phase of the project while, Section 4 concludes this paper.

## 2 MOBILITY 2.0 concept

The concept of the multi-modal commuting assistant for FEVs envisions a distributed application based on the in-vehicle equipment of a FEV and the smart-phone of a driver that supports its owner by providing optimal travel advice during the FEV use, but also during the rest of the journey. The

application is supported by traffic information, using external services and data provided by road side units. If congestion is unavoidable and passing through congestion would deplete energy resources of the car, it might also advise to park the car at a nearby charging station and switch to public transport. Calculations will also include range estimation that takes into account the desired charging profiles and driver profile versus journey topography (e.g distance, slopes) and current traffic conditions to ensure that the car is properly charged for the way back. The system will also manage charging-spot reservation to ensure that charging spots are available when the FEV reaches the charging area.

Consequently to the above, the EU FP7 project MOBILITY 2.0 aims to focus on the research and development of an in-vehicle co-operative commuting assistant for FEVs which seamlessly takes the driver through the three-stage process of available parking reservation, vehicular navigation through sparse areas, and navigation via public transport in dense urban areas. While some previous projects have worked on the research and development of multi-modal nomadic navigators [references missing], FEV-specific aspects such as grid-friendly, community friendly spot reservation and the balancing of FEV range against the estimated duration of the commute shall be also addressed by Mobility2.0. The next section identifies the technical and scientific issues addressed by Mobility 2.0 project enabling the optimal deployment of such e-mobility applications. These co-operative applications will also be validated through integrated field trials at Barcelona and Reggio Emilia test sites.

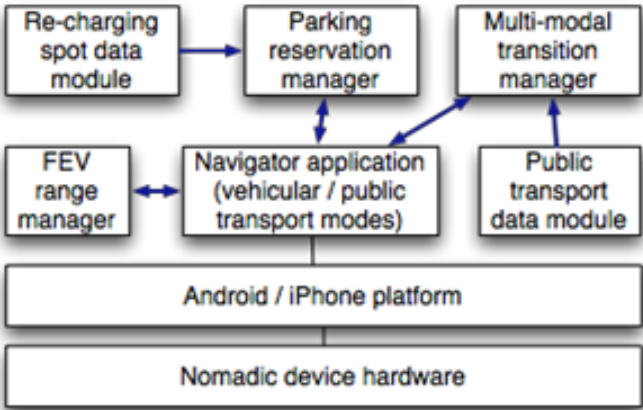


Figure 1: FEV commuting assistant application concept

Mobility2.0 will develop the co-operative FEV commuting assistant application for the most prolific nomadic device platforms, such as Android and iPhone. Figure 1 shows the software components that this application will comprise. The multi-modal journey planner application component is in the

centre, as it runs in the foreground and provides the interface for user interaction. The other complementing software components run in the background.

## 2.1 Route planning and journey optimization

The system specified within MOBILITY 2.0 supports two fundamental use cases in the project described as “journey planning” and “journey adaptation”. While journey planning refers to the case where a user requests route recommendations for a journey from A to B that respect his “tolerated” means of transportation and other personal preferences (while the FEV range has been predicted to be enough for all combinations of driving parts of this journey), journey adaptation is needed when FEV of a user is running out of battery (or range), which requires to search for appropriate re-charging stations and adapt the user-selected route.

With respect to “journey planning”, the following objectives are addressed by the specification of the architecture defined in the project:

1. The route recommendation algorithm supports both optimizing the route of a single user (e.g. individual travel time), and optimizing the routes of all users; in the latter case, since route recommendations are made on the fly, the algorithm will return a route which is not optimal for the user, but is expected to minimize the overall travel time, by avoiding to use a charging station that might be more useful to another user.
2. The route recommendation algorithm supports travel time, distance, and eventually also monetary costs as optimization criteria.
3. The route recommendation algorithm supports maximum walking distance, maximum biking distance, and banning of transportation means as additional search constraints.
4. The route recommendation algorithm does not aim to optimize for the energy grid itself. Indeed, it is assumed that such objectives will be fed into the system through dynamic energy pricing at re-charging stations.
5. The route recommendation algorithm supports multiple intermediate stops only if those stops do not require additional recharging. Consequently, charging at multiple stations during one journey will not be considered.
6. As part of the route recommendation algorithm, a filtering of the feasible driving sub-routes is always performed offline based on the estimated FEV remaining range.
7. Required energy in order to successfully complete a desired route may also be an output of the Range Manager component in order to allow the “journey planning” algorithm to accordingly plan duration of required charging during stops.

With respect to “journey adaptation”, the following objectives will be addressed by the architecture:

1. While the FEV moves, the Range Manager performs a real-time monitoring of remaining range (in km).
2. In case that the FEV is running out of battery (range is not enough to reach the next planned stop, with a lower bound to be specified), the system informs the user.

## 2.2 Efficient broadcasting of FEV recharging spot data

The cooperative commuting assistant for FEV needs to have up-to-date status information on the possible recharging spots. The parking reservation of a suitable location can be then negotiated during the journey planning stage. Charging spot information needs to be available both at the nomadic devices, as well as in vehicles. For the latter, we will develop and implement a charging spot notification mechanism using geo-broadcasting over 5.9 GHz co-operative systems. Furthermore, we are specifying a protocol for charging spot reservation.

## 2.3 Roadside infrastructure for 5.9 GHz co-operative networks

A major deployment challenge for the realisation of large-scale co-operative vehicle-infrastructure communications is related to the effort and costs of deploying the involved road-side communications units. The questions around its financing, installation, and maintenance are unresolved yet. A straightforward solution is to utilise FEVs plugged for recharging as road-side communication units, which maintain broadband connectivity with the infrastructure through the smart-grid network. Mobility2.0 will consider this enabling aspect that FEVs play for the large-scale introduction of 5.9 GHz co-operative networks.

## 2.4 Access to FEV data

In order to give the Mobility 2.0 system access to FEV-specific data such as battery capacity and remaining driving range, Mobility2.0 will specify the required data exchange interface between the vehicle and a central route planning system and contribute it for standardisation. (Since a significant portion of FEVs may be also be produced by the conversion of traditional vehicles into FEVs - especially in the near and medium terms - it is important to develop a solution that is applicable to both vehicle types.).

# 3 Software architecture

The Mobility 2.0 platform relies on a client-server based architecture, in which the user application running on the nomadic device, as well as the onboard unit in the full-electric vehicle, act as a client, and the Mobility 2.0 service as a centralized server. According to the high-level architecture specified

in Task 3.1 of Mobility 2.0, communication between clients and the server will be carried out over 3G. There will not be any direct communication between the vehicle and the nomadic device.

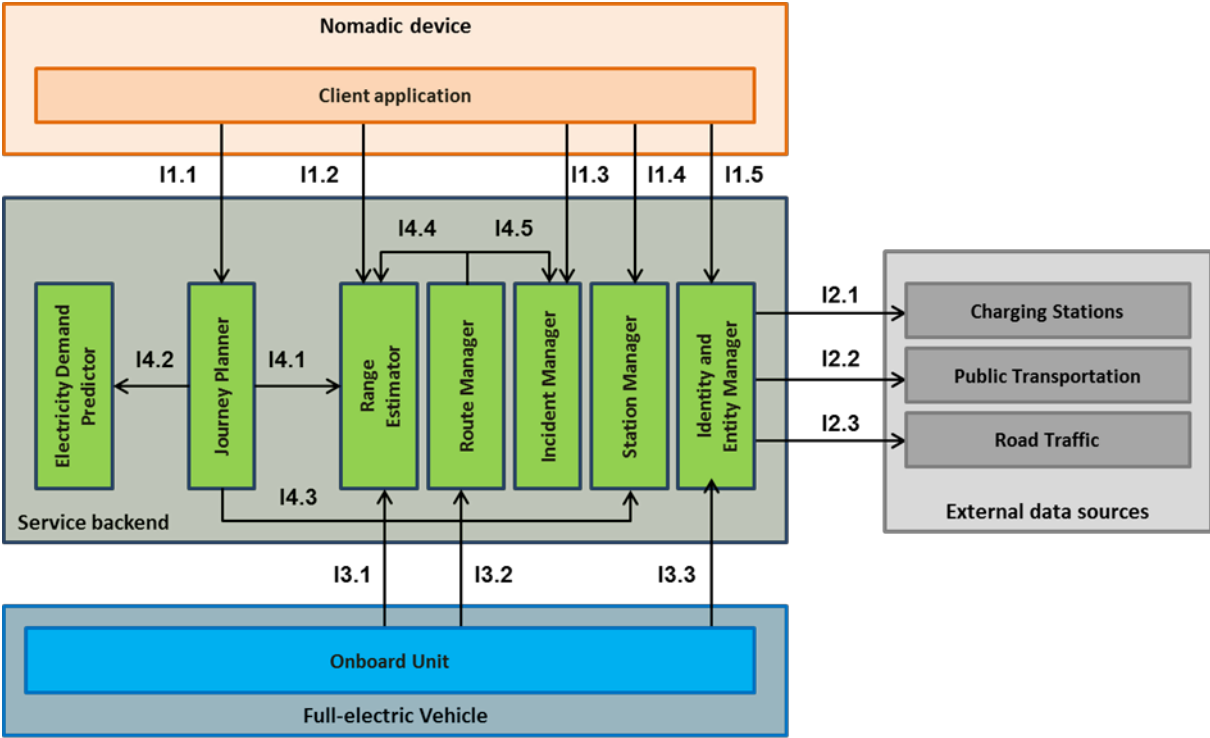


Figure 1: high-level system architecture and required interfaces

Figure 1 illustrates this high-level architecture again and lists all interfaces that exist between the systems involved. Most importantly there are the interfaces I1.1 to I1.5 between the client application on the nomadic user device and the components of the Mobility 2.0 service backend. As the arrows indicate, these interfaces are used by the client application, i.e. the methods offered by the interface are invoked from client side (pull mechanism). The second set of interfaces comprises I2.1 to I2.3 and is responsible for collecting information from external data sources such as re-charging / parking stations, public transportation operators, or traffic information systems. This information is envisioned to be pulled from the Mobility 2.0 service backend periodically. The third set of interfaces comprises I3.1 to I3.3 covers the support for periodic status reports from vehicles to the Mobility 2.0 service backend. The last set of interfaces comprises I4.1 and I4.5 covers (internal) interactions between individual components of the service backend.

The following subsections provide a more detailed description of the Mobility 2.0 service backend components, and sketch the graphical interface that is shown to the user through the client application in order to ensure a proper user experience. A complete specification of the interfaces offered by the Mobility 2.0 service backend is provided afterwards in Section 3.

3.1.1 Service Backend

This section covers the alignment and description of the components that comprise the Mobility 2.0 service backend. It does not aim to propose certain technologies that shall be used for the implementation, but rather the logical layering and decomposition of tasks and responsibilities into software components. Figure 2 illustrates the alignment of these components.

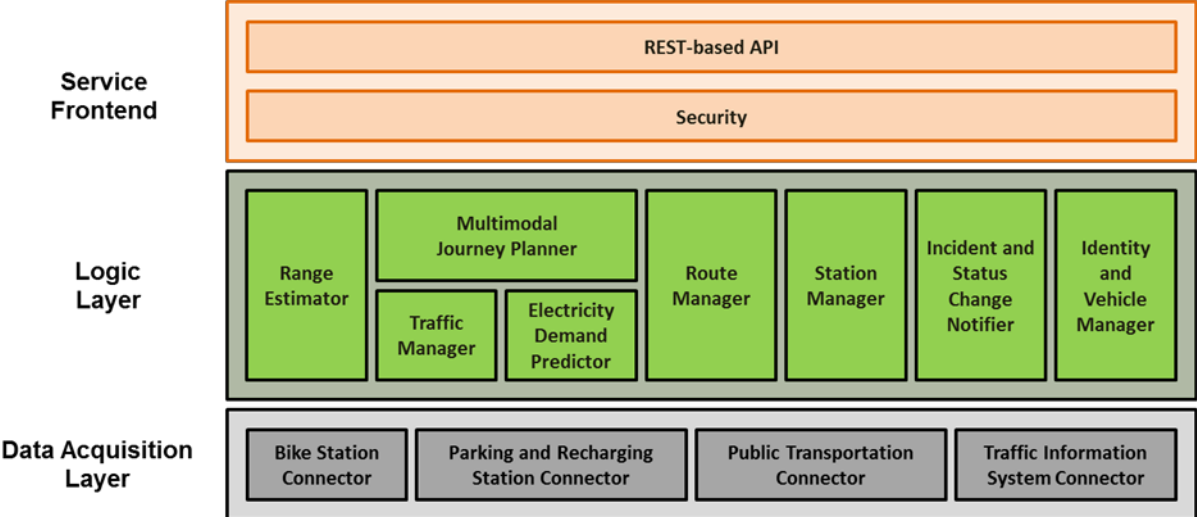


Figure 2: Software architecture of the Mobility 2.0 service backend

*Service Frontend*

REST-based API: this component exposes the functionality of the core components to the client applications(s) over HTTP, and essentially implements the controller that orchestrates the exposed methods of the components. To ensure that third parties can not follow the communication, SSL is employed between client and server.

Security: ensures that only trusted users and vehicles can use the service. Each user and vehicle needs to authenticate itself before being able to use the RESTful API.

*Logic layer*

Identity and Vehicle Manager: manages all user accounts, registered vehicles, and is responsible for carrying out authorization or associating users with vehicles.

Station Manager: keeps track of available parking and recharging slots. It is the central unit to list available parking and recharging slots (independent of the station operator), but is not involved in the actual reservation process. Reservation is negotiated between user and station operator directly.

Traffic Manager: based on the information available to the Mobility 2.0 system, this component keeps track of the current traffic conditions in the road network. It is queried by the Multimodal Journey Planner to update the travel time costs within the search graph of the Multimodal Journey Planner, and provides estimates of future traffic conditions in city areas or even individual streets.

Multimodal Journey Planner (MJP): performs multi-modal journey planning according to the given preferences of a user (e.g. maximum time available for the trip, maximum walking distance, maximum number of transfers, etc...) and the selected optimization criteria (e.g. travel cost, travel time, travel distance). It is the main component responsible for route recommendations and depends on input provided by the Range Estimator, the Traffic Manager, as well as the Station Manager.

Incident and Status Change Notifier: keeps track of disruptions (traffic jam, metro stop being closed, etc...) and status changes (delays, etc.) occurring in the road and public transportation network. Client applications can periodically query this component for updates.

Range Estimator (RE): estimates the remaining range of the vehicle, depending on the driving behavior of the user, the current state of charge of the vehicle, the route profile, and the current weather or traffic conditions. Both a pro-active (offline) and a re-active functionality (real-time) may be supported. Knowing the future energy consumption, the required battery energy in order to successfully cover a given range can also be provided by the Range estimator if requested.

Electricity Demand Predictor: this component provides, based on the estimated arrival times of vehicles at their pre-selected re-charging stations, the estimated energy level upon arrival, and the required energy level upon departure, an estimate of the electricity demand in the city, a city area, or only at a single recharging station. It also calculates a virtual price for re-charging stations which will be considered by the journey planner when generating route recommendations.

Route Manager: the route manager keeps track of the current energy level of a vehicle, and the events that relate to the selected route of a user. For instance, the route manager will periodically re-estimate the energy level of all vehicles upon their arrival at a re-charging station in order to keep the electricity demand prediction component up to date. It further adjusts the arrival time estimate for each of these vehicles and provides such updates to the electricity demand prediction component as well.

#### *Data acquisition layer*

Bike Station Connector: provides real-time information about existing bike stations and the number of available bikes at each station, following the JSON format.

Parking and Recharging Station Connector: provides real-time information about existing parking and recharging stations, including the number of available slots. Test site specific data formats are further converted into the generic data format of the Mobility 2.0 platform.



Traffic Information System Connector: provides real-time information about the current traffic conditions in the city, and converts the information into a generic data format usable by the Multimodal Trip Planner component. Since the level of street segmentation used by the traffic information system does not necessarily match the level of segmentation available in Open Street Maps, a mapping of segment identifiers has to be implemented here as well.

Public Transportation Connector: provides information about the time tables of public transportation. If there are multiple public transportation operators, there can also be multiple public transportation connectors, one adapting to each system interface. Furthermore, this connector provides real-time trip updates and service alerts and translates all data into the internal data format of the Mobility 2.0 platform.

### 3.1.2 Client Application

The client application provides a front-end to the Mobility 2.0 service backend and enables the user to interact with the system. The software architecture of the client application is not specified in this document since many different mobile phone operating systems exist, each of which applying different software design principles. Section 4 will therefore specify the graphical user interface only, addressing the required screens being presented to the user, the information each screen will show, as well as the interaction flow between screens.

## 4 Future work and conclusions

The systems and solutions developed within the project will be tested and validated in two different test sites. Reggio Emilia (Italy) and Barcelona (Spain) will be the two cities acting as pilots in MOBILITY 2.0. Both cities are clear examples of FEV promoting cities in Europe.

## Authors

Alma Solar is Electronic Engineer - networking specialization - from the Polytechnic University of Valencia (Spain). She has worked in the past in Siemens (Valencia, Spain) and Telefónica Investigación y Desarrollo (Madrid, Spain). She has experience in advanced transport and traffic ICT services and solutions for final users and collaborative applications. She is currently involved in several EU RTD mobility related projects, such as MOBINCITY and MOBILITY 2.0 and she is coordinating MOLECULES (electromobility CIP) project.

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