eTelematik: ICT-System for Optimial Usage of Municipal Electric Vehicles

Outline of System Requirements, Implementation Design and Field Test Results

Steffen Späthe, Wilhelm Rossak
Department of Computer Science
Friedrich Schiller University Jena
Jena, Germany
{steffen.spaethe, wilhelm.rossak}@uni-jena.de

***Abstract*—Electrical vehicles are not only passenger cars but also commercial vehicles and, in special, municipal vehicles. Their acceptance and usage depends primarily on everyday usability, aiming for a smart vehicle with intelligent energy and range supervision and driver support. In our funded research project eTelematik, we conceptualized, implemented and proved an Information and Communication Technology (ICT) System with directly connected vehicle components, driver interface and backend applications. In order to expand the usage of electric vehicles, we predict energy consumption of complex work task sets and guide vehicle drivers while driving.**

Keywords-Municipal vehicles; ICT-support for fully electric vehicles and electric vehicles with range extender; range prediction; mobile client; in-car module.

I. INTRODUCTION

Worldwide electrical vehicles are seen as mobility's future. Primary focus in this vision is mainly on private cars [1]. Commercially used vehicles however, have a much better starting point for electrification. Based on pre-scheduled tasks and daily high usage work the capability of commercial vehicles can be predicted. At the current state of development commercially used, fully electrical vehicles are not able to fulfill a full day's work without recharging. Therefore, hybrid vehicle concepts are developed and currently in advanced prototype state. A special class of commercial vehicles are municipal vehicles. These universal vehicles can be used with different setups and add-on structural parts in various scenarios.

In our research project eTelematik, we developed an Information and Communication Technologies (ICT) based system, which supports daily commercial usage of electrical municipal vehicles and enables new usage scenarios with hybrid vehicles.

The project eTelematik was a federal funded research project between 2012 and 2014. The consortium included four main partners [2]:

1. EPSa GmbH: industry, electronics and communication devices
2. Navimatix GmbH: mobile and server applications
3. Friedrich Schiller University Jena: research, distributed software systems, range estimation´
4. HAKO GmbH Werk Walterhausen: electrical municipal vehicles

The paper presented here focuses on the overall perspective on project results. While funding elapsed many questions are left open and are subject to further research and development work.

The remainder of the paper is organized as follows: In Section 2 we will provide an overview of the project´s overall ICT architecture including the main challenges of our distributed system. From there we will highlight the usage of collected data inside the vehicle and on backend systems. In section 3 we will present some information about our field test. We close with a short review of goal reaching in section 4.

II. THE ETELEMATIK PROJECT

Main focus of the project was the creation of a complete ICT infrastructure to enable an improved usage of electrical municipal vehicles.

Our main requirements to this system were

a) to gather data from mobile electrical vehicles and store them in a central universal database,
b) to interpret gathered data to evaluate the influence of various parameters on energy consumption during the fulfillment of certain work tasks with required work equipment,
c) to adjust the internal energy consumption and range prediction model with computed factors of influence and
d) to support the driver with information about estimated and real energy consumption of current and scheduled work tasks irrespective of the status of the connection to the central server.

Excluded from the project focus was the development of a new work force management or fleet management/ optimization system. Thus, all required business data had to be provided from an external fleet management system via designated service interfaces.

Basing on these requirements we developed our system as schematically shown in figure 1.

 ISBN: 978-1-61208-414-5

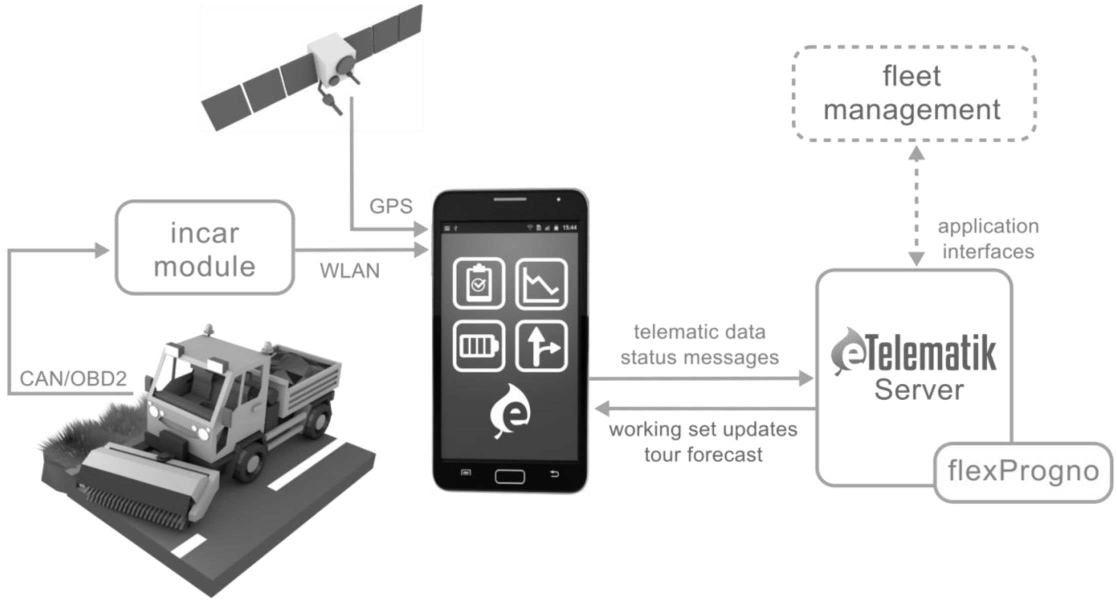

Figure 1. eTelematik system architectur overview (adapted figure, based on original by Johannes Kretzschmar, University Jena)

The eTelematik solution consists of a communication hardware (named “in-car module”), a mobile application (named “mobile client”) and a central server (named “central instance”) with a prediction model (named “flexProgno”).

Externally computed work task sets are evaluated concerning their practicability in our central instance *eTelematik Server*. We use our energy consumption and range prediction model *flexProgno* to estimate the power consumption for every single part of the given working set. While power consumption depends on various parameters like vehicle model, payload, environmental temperature as already shown in [3], we need to know more about the work task, required add-on structural parts and settings of them. Also we require knowledge about the concrete routing and whose elevation profile between different work task places. We use the commercial available route calculation service and map height services of project partner Navimatix GmbH to gather this data.

If a working set is estimated as accomplishable, the assigned driver gets this set shown on his mobile client.

Inside the vehicle the communication hardware, developed by EPSa GmbH, collects vehicle specific data in real-time, aggregates and sends them to the mobile client. Communication between the communication hardware and the vehicle is realized by Controller Area Network (CAN) connections. The mobile client, developed by Navimatix GmbH, is an android application running on established consumer devices. The mobile client informs the driver about the actual operating status of the vehicle, the current status prediction based on the assigned working task set and the probability of fulfillment of this set. All collected vehicle data combined with sensor data from the mobile phone are transferred to and stored at the central instance.

Figure 2 shows the internal conceptual system design of the mobile client application. The mobile client is subdivided into a user interface related part and some background services. While the data storing modules are responsible to realize business logic which is used by the UI module, the ICM Communicator Service takes care of establishing and keeping alive connection to the in-car module. We use plain TCP socket connections at this communication channel to minimize transport size and delay overhead. The eTele App Communicator Service realizes the reliable communication to the central instance. All other services, background as well as UI-related, use this service to communicate to and receive data from the central instance. At this channel, we use HTTP as transport layer. As our JBoss Application Server based central instance is realized using Java Servlets and Enterprise Java Beans, HTTP is a natural choice. As payload we used data objects with an own implemented key-value based object serialization which represents our business data.

To summarize our system has to handle following data from central instance to vehicle:

- master data of vehicles and drivers
- general and vehicle specific configuration setting for communication between in-car module and mobile client
- current work task sets depending on logged in driver

From vehicles to central instance we send:

- updates of work task status
- vehicle’s positions and velocity
- electrical vehicle specific measurements

The electrical vehicle specific measurements and especially their representation on in-car communication buses vary between vehicle manufacturers and even between vehicle types of one manufacturer. Within our project consortium we are able to gather and transfer following electrical vehicle specific measurements:

- state of charge
- primary battery voltage
- current in high voltage circuit
- connection state, settings and power of battery recharger
- state and settings of range extender (if applicable)

 ISBN: 978-1-61208-414-5

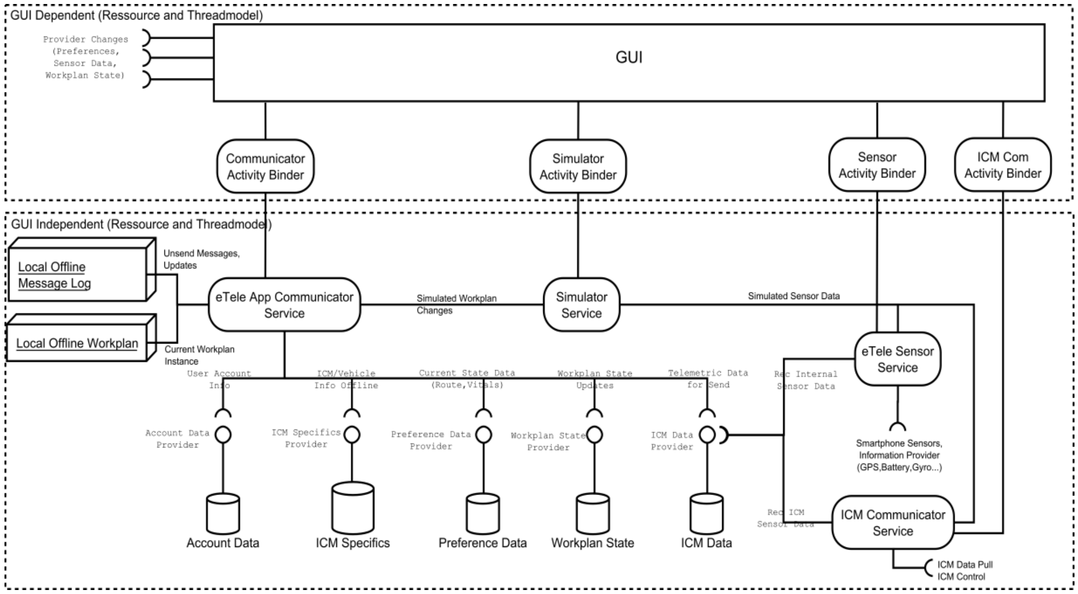

Figure 2. eTelematik mobile client´s internal module overview

These data are used in different situations. Inside the vehicle the data support the driver in driving between work task places of action and while task fulfillment. On server side, we use recorded data in different analyses.

Inside the vehicle we are able to realize “enhanced foresighted driving”. Because we know basing on the scheduled work task sets, which route has to be to driven and what kind of working task has to be accomplished, we are able to predict if this planning is still valid. Usually, only average statistics about energy consumption per kilometer are available to the vehicle and the driver. We know the concrete route to drive as well as the required settings of add-on components. Thus, we are able to predict the required energy consumption on a much more detailed basis. This advanced, detailed knowledge allows us to warn the driver that he will not reach his destination, even if the average statistics would tell him so. Alternatively, we can relax him in situations where average statistics would show a much to low range, for example when the planned route has many downhill sections. Furthermore, we can delay in hybrid cars the usage of the range extender when it would be triggered by the vehicle’s management system because we know when the user’s preferred charging stations are in reach.

By doing so, we are able to optimize the battery usage and to extend the usability of electrical vehicles.

In vehicles with range extender we can optimize the point in time for recharging. In certain situations, work tasks have to be fulfilled without any avoidable emission, e.g. noise or exhaust. If recharging is only controlled by battery state of charge it could happen, that the driving to the workplace is realized fully out of battery and that the recharging has to be started at working place. With our knowledge about the complete work task set and desired or required restrictions in work task fulfillment we can foresee and avoid such situations.

On server side, we use recorded data of the vehicle in different scenarios.

A long-term use case which is very important to vehicle manufactures as well as to the vehicle owner, is predictive maintenance. With data mining technics, we are able to detect deviations in characteristic gradients long before the vehicle breaks down. This is of particular interest to our project partners due to the lack of long-term experience with the completely new designed power train and the used battery system.

In addition, this process enables for the first time insight into exhaustive detailed real world usage records for these vehicles. This information is very helpful to vehicle manufactures for further improvements and new developments.

A short-term use case is monitoring of overall resource consumption for certain work tasks. To date the direct assignment of fuel consumption to single work tasks is not possible. Since we record work task state changes as well as energy consumption parameters continuously we are able to match them.

Inside our project’s system we also process recorded data for intrasystem usage. Main task is to adjust and improve our energy consumption and range prediction model flexProgno. Our model is based on assumptions like required energy stays equal if all influencing parameters do not change or stay very close to situations before. Initially we did not have many vehicle specific data. By processing recorded data the vehicle specific parameter set gets more accurate over time. The basic approach of our model is shown in [4].

Energy consumption does not only depend on vehicle or work task parameters, but also on driver characteristics. Hence, it is important to include the driver’s start-up and stop behavior in energy consumption prediction. Since these parameters cannot be measured beforehand they need to be determined from the recorded data.

As we developed our system from scratch we designed a long running field test. We built up a complete system installation to validate the system’s long term stability, data transfer reliability especially in areas with unreliable mobile network connection and to validate and harden our prediction model.

In our build up test, we installed our system components in five electrical vehicles. These vehicles were used on a regular daily basis.

The field test is a still ongoing process but we like to emphasize some preliminary results.

A) Our system setup is running very stable over all components. During the development there was some doubt about wireless local area network (WLAN) communication between in-car module and mobile client. However, we do not register any significant disturbance in this communication channel. All relevant data provided by the electrical vehicles in the field test were recorded by the in-car module and were transferred properly to mobile client.

B) We succeeded in establishing a robust communication between mobile client and central instance. Even in our test region where mobile network coverage is very patchy, we had no data loss.

C) Synchronization of master data as well as measurement data between mobile client and central instance is working very solid even if network connection gets lost while transfer. Thus, required offline capability of the mobile client is achieved.

Our field test is still in progress and we are still collecting data. The respective data evaluation with primary focus on our range prediction model will be published separately.

III. Summary and Future Work

Based on the evaluation of our long-term field test we can state that we achieved our primary goals. Quantity and quality of recorded and transferred data are satisfying, data transfer reliability is sufficient and offline capability for mobile client is achieved.

Therefore, we can determine that our selected system design and implementation are adequate to meet our overall requirements. Though, we have to rerate our selection of mobile phone as primary communication channel. We deployed mass market mobile phones in the field test. To date we did not have substantial failures. However, based on other tests we expect thermal problems in very cold and warm to hot situations. These problems will become more seriously when running more applications and parallel tasks on the mobile phone's hardware.

Therefore the partitioning between in-car module and mobile client has to be reviewed very carefully. An alternative approach could be to transfer all permanent running processes of data collection and aggregation to the fixed-powered in-car module. This could as well include data transfer from and to the central instance. This process should be realized in a proxy-like way to keep this functionality transparent to the mobile client. The main function of the mobile phone still has to be the communication to the driver of the vehicle. This includes the exchange of information about working sets, as well as electrical vehicle state of charge, and driving instructions, to reach optimal range and energy usage.

A disadvantage within this alternative approach is the limited updatability and extensibility of the in-car module. The software for the in-car module has to be written system-specific and very closely fitted to the underlying hardware. One option to overcome this drawback would be to implement a scripting language like lua to encapsulate high level logic from lower hardware-near level.

Still many questions and tasks are left open. Our work will be continued, partly in cooperation with the federal funded project call “Smart City Logistik Erfurt” (SCL) [5].

In SCL, we address aspects of inner city freight logistic processes with full electric vehicles. The logistic partners of SCL intend to deploy available medium sized electrical vehicles into their business as freight transporters for the last mile, from the city's perimeter to the final destination. The project's focus is on ICT support to optimize vehicle's utilization and integration in existing fleets and processes.

Therefore we have to adapt our in-car module to the selected vehicle models. The driver assistance mobile application needs adjustments to meet the specific needs in delivery logistic applications. Our range prediction has to be adjusted to the new domain as we have differing influence factors like weight or specific vehicles accessories. In SCL we will not only validate existing working sets. Implementation of route calculation and tour optimization with electrical vehicle´s additional restrictions will be an important task. Overall we have to improve usability and user experience in our driver assistance application as well as in backend systems user interface, which was not in focus of eTelematik but is undoubtedly important to bring our research and development into real world applications.

IV. Acknowledgment

We would like to thank all members and partners of eTelematik research project, especially S. Gebhardt from HAKO GmbH for long lessons on battery chemistry and vehicle driving dynamics.

References

[1] S. Lukic, Z. Pantic, “Cutting the cord: Static and dynamic inductive wireless charging of electric vehicles.”, Electrification Magazine, IEEE 2013, vol. 1, no. 1. pp. 57-64.

[2] eTelematik: Project website. [Online]. Available from: http://www.etelematik.de/ 2015.02.23

[3] V. Schau et al., “SmartCityLogistik (SCL) Erfurt: Deriving the main factors that influence vehicle range during short-distance freight transport when using fully electric vehicles”, LBAS – Conference on Location Based Applications and Services, Jena, Germany, 2013, pp. 101-108, ISBN: 978-3-8325-3813-2

[4] J. Kretzschmar, F. Geyer, S. Späthe, W. Rossak, “eTelematik: Prognose und Ausführungsüberwachung elektrifizierter kommunaler Nutzfahrzeuge”, LBAS – Conference on Location Based Applications and Services, Jena, Germany, 2013, pp. 119-125, ISBN: 978-3-8325-3813-2

[5] Smart City Logistik Project website. [Online]. Available from: http://www.smartcitylogistik.de/ 2015.02.23