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Automated Valet Parking using IoT: Design, user experience and business opportunities

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Abstract

Automated Valet Parking can be made more efficient with Internet of Things (IoT) techniques for e.g. reservation and detection of free parking spaces. In the framework of the H2020 AUTOPILOT project, a prototype vehicle and service have been developed and demonstrated in Tampere, Finland. The vehicle uses a reservation application for assigning the parking place and a traffic camera for detection of obstacles in the projected path and on the reserved parking space. User tests have been performed to assess the user acceptance of the service. The business opportunities of the services have been assessed in workshops with stakeholders.

Keywords: Automated vehicles; Internet of things; user acceptance; Automated Valet Parking

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1. Introduction

Automated vehicles use in-vehicle sensors to monitor the environment in order to perform the driving task. The in-vehicle sensors allow to monitor objects up till about 200 meter in front of the vehicle. Through communication with the infrastructure, vehicles can retrieve additional information on e.g. hazards outside the sensor range. Internet of Thing technologies allow to collect information of a vast amount of sensors, and hence provide additional information which allows the vehicle to optimize the driving task.
The AUTOPILOT project, which is co-sponsored by the European Commission through the H2020 programme, studies how automated driving can benefit from the Internet of Things (IoT). The project pilots four different driving modes (automated valet parking, urban driving, highway pilot, platooning) where IoT enhances, accelerates and/or enables automated driving. The use cases were piloted in five test sites around Europe located in Vigo (Spain), Tampere (Finland), Versailles (France), Livorno (Italy) and Brainport (the Netherlands). In Tampere, the automated valet parking and urban driving are piloted.

The main concept of the Automated Valet Parking (AVP) is that the driver leaves the vehicle at the drop-off point and the vehicle parks itself autonomously. The vehicle returns to the pick-up point at the request of the driver. The parking maneuver is controlled either by a local Parking Management Service (PMS) or by the driver itself through an application at a mobile phone. Main advantages of automated valet parking include the time gain for the driver and the possibility to optimize land use by parking vehicles closer to each other.

Through using IoT, the Parking Management Service has a complete view of the reservation status of the different parking spaces. The vehicle does hence not have to rely on its environmental sensors to scan the parking facility for a free spot.

Automated Valet Parking systems are currently under development and piloted by several vehicle manufacturers. For instance, Mercedes and Bosch are demonstrating an Automated Valet Parking service without safety driver at the Mercedes-Benz museum in Stuttgart (Bosch, 2019). In this implementation the parking maneuver is controlled from a mobile phone app by the driver, and the vehicle maneuvers using sensors in the infrastructure. Through relying on information from the infrastructure instead of on LIDAR and radar sensors, the vehicles can be technologically less complex (Davies, 2019).

Standardisation activities regarding Automated Valet Parking are ongoing in ISO (ISO 23374, 2019). In the standard proposal, the control of the vehicle at check-in is passed by a driver command to the local Parking Management System. The vehicle drives autonomously to the assigned parking place, either using its own environmental sensing capabilities or through information provided by the Parking Management System. Control of the vehicle from the Parking Management System requires a network of sensors in the parking facility in order to detect free parking spaces and to identify obstacles in the parking facility.

Within the AUTOPILOT project, Automated Valet Parking is piloted in three sites, using IoT services for the management of the parking maneuver and IoT devices for detecting free parking spaces and obstacles. The AUTOPILOT project has developed assessment methods to analyse the impacts of the services on user acceptance and quality of life, as well as on business. This paper describes the development of the Automated Valet Parking service in Tampere, the user tests to assess the user acceptance, and the business impact assessment with stakeholders.

2. Development of the service

In the Tampere implementation of the Automated Valet Parking service, the Parking Management System (PMS) reserves a parking space through a third party application from Mattersoft Ltd. This application has been developed for the reservation of urban freight delivery parking places in the framework of the H2020 TransformingTransport project.

Fig. 1 (a) Research prototype vehicle Marilyn; (b) mobile road side unit MARSU

The vehicle used for the pilot is VTT's research prototype vehicle Marilyn 2.0 (Fig. 1a). The vehicle is a Citroen C4, which has been updated for automated driving by adding electronically controlled actuators to the brake pedal, steering wheel, throttle and gear lever (Scholliers et al, 2018). Advanced environmental perception sensors, including LIDAR and radar, are installed in the vehicle.

A traffic camera at the parking place checks whether the projected route is free of obstacles and verifies which parking place is free. The traffic camera is installed at the mobile roadside unit MARSU from VTT (Fig. 1b). This mobile roadside unit consists of GPS receiver, communication equipment and cameras. The image of the camera is processed locally at the roadside unit. The camera uses neural network technology to decide whether there are objects present in a specific area, and returns the availability of the different sectors.

The major vision of the developed service is that the driver leaves the vehicle at the drop-off point, at which the PMS takes over the control of the vehicle. The PMS determines the parking place and the vehicle moves in unmanned mode to the reserved parking spot. At request of the user, the vehicle is returned to the pick-up point. In the demonstrations a safety driver is always in the vehicle.

When the vehicle is at the drop-off point, the driver makes the parking request. The Parking Management System selects a free parking place and makes a reservation request. Based on the presence of obstacles in the parking area, the route is selected. The Parking Management sends the reserved parking spot and the obstacle free path to the vehicle. After confirmation, the vehicle starts moving in automated mode to the parking space.

In order to assure accurate positioning two different methods have been tested during the pilot: UWB based positioning from HERE and RTK-GPS. The HERE positioning system has been developed for indoor positioning, and consists of a network of UWB transmitters on the parking facility and two UWB receivers on the vehicle. The vehicle calculates its position directly from the signals from the UWB receivers. For the Automated Valet Parking outdoor tests, RTK-GPS is used.

The pick-up process is similar to the drop-off process: the user requests pick-up, and the PMS assigns an obstacle-free path, based on the information from the traffic camera. After the Parking Management System issues the return path, the vehicle starts moving to the pick-up point.

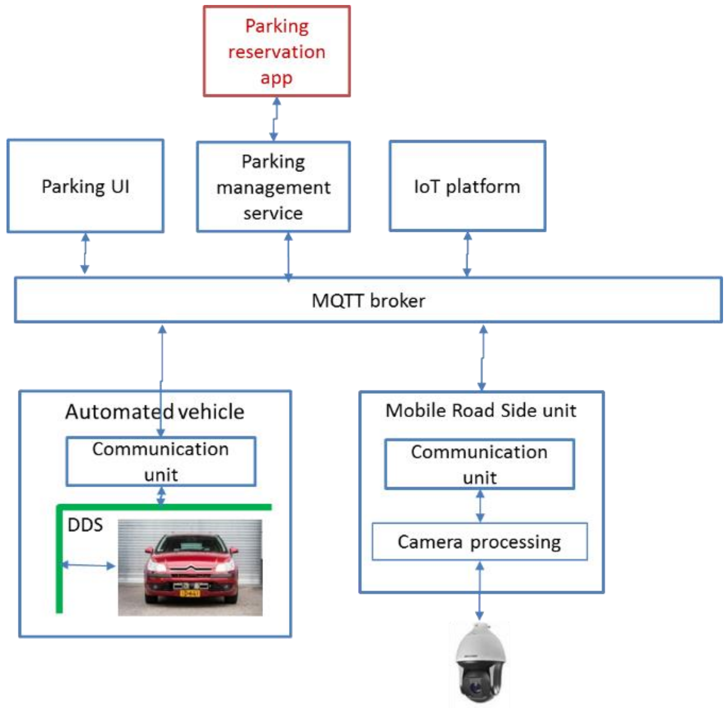

Fig. 2 - Architecture of the Automated Valet Parking system in Tampere

Fig. 2 shows the architecture of the AVP pilot. Both the vehicle and the mobile RSU internal network are based on data distribution network (DDS). Information exchanged between the vehicles, RSU and the services, like the parking management service, is based on MQTT, and is being sent to an open oneM2M IoT platform (openMTC). Communication between vehicle, mobile RSU and the IoT platform uses available mobile commercial network (4G/LTE).

The Parking Management Service (PMS) controls the parking maneuver, and also communicates with a graphical user interface, on an Android tablet, over the IoT platform. This user interface can either be handled by the driver of the vehicle or the parking infrastructure operator. A parking place is requested from the Mattersoft application, using REST user interface. The traffic camera uses artificial intelligence to detect obstacles on the projected route Based on the result of the camera and the reserved parking place the PMS calculates an obstacle free trajectory. After confirmation in the graphical user interface, the PMS sends the obstacle free path to the vehicle and then the vehicle starts moving to the parking place. Through the vehicle's own sensors obstacles on the path can be avoided during the parking maneuver.

Fig. 3 - (a) Automated parking manoeuvre of the VTT parking place at Tekniikankatu, Tampere; (b) map of the area with the alternative routes to the parking spaces

The parking maneuver has been tested at the parking place of two VTT facilities in Tampere. Fig. 3aFig. 3 - (a) Automated parking manoeuvre of the VTT parking place shows a snapshot of the parking maneuver at Tekniikankatu. The mobile road side unit, which monitors obstacles on the parking space and on the route to the parking place, can be seen at the left side of Fig. 3a. Fig 3b. shows a map of the area, including the position of the RSU with the traffic camera, and the area monitored for obstacles. In case of an obstacle when targeting for parking places 1-3 in Fig. 3b, the lower route will be selected.

User tests and technical validation were performed at the Niittyhaankatu premises of VTT. Table 3 lists some of the transmission times which were logged during the technical tests. Transmission from the vehicle and the RSU to the MQTT broker require less than 200 ms. For the communication to the IoT platform, the transmission times are a bit longer, and involve a polling at a frequency of about 2 Hz, but all messages are at the IoT platform in 1 second.

Table 1. Transmission times

Transmission end points	Average (*ms*)	St. Dev (*ms*)	99% percentile (*ms*)
From the vehicle to the PMS	168	75	211
From the RSU to the MQTT broker and the PMS	26	58	51
From the RSU to the IoT platform	572	292	1066

3. User Acceptance tests

The user acceptance of the service was tested with field tests. For these tests, 29 naïve test users of different gender and age groups were recruited by an external service provider. Prior to the test experience, the test users received a short introduction of the service and filled in a questionnaire on their expectations towards the service. As there has always to be a safety driver in the vehicle, the users were participating as passengers, but were asked to imagine being in the driver’s seat. During the tests, they manipulated the user interface of the Parking Management System, controlling the start of the parking maneuver and the pick-up maneuver.

After the completion of the test, the participants filled in a questionnaire about the tested AVP service as well as background questions. In addition, two focus group discussions were arranged with eleven participants in total. The aim of the focus groups was to discuss the service in further detail and to get input on the background and context related to the experience and the users’ opinions. The main discussion points were related to potential benefits and concerns, travel behaviour, privacy issues and suggestions for improving the service.

The main input data for user acceptance evaluation were the user test questionnaires (pre, post and background) and focus group discussion transcripts, which formed for comprehensive results of the tested service from the users’ point of view, as well as the potential benefits and concerns addressed by the users. The majority of users found the experience positive and the service useful. They assessed that the service would decrease their stress related to parking. The participants showed concerns regarding data security and liability in case of accidents or malfunctioning.

4. Business impact assessment

Despite the high expectations on new business opportunities enabled by IoT, the progress towards commercial successes has been slow, not only within ITS but in many other fields as well. Markendahl et al. (2017) summarize the main obstacles for introduction of IoT:

- Specific IoT solutions often tend to be a small part of the overall solution and hence it may be too small in order to be a sustainable stand-alone business
- Uncertainty and/or lack of knowledge about which overall services or business the IoT solution may be part of
- Fragmentation due to the diversity of parallel “closed” solutions that lead to insufficient scalability
- Distrust and hesitation among actors to share common and open platforms and to share data
- Fear of changing the own business model

The procedure for assessing business impacts in the AUTOPILOT project has been developed to take into account these obstacles; see Fig. 3 (Nikolaou, 2018). Especially it has been recognized that there needs to be mechanisms or activities to support development of new partnerships - or business ecosystems (Valkokari, 2015) - in parallel with technological development to be able to advance towards feasible commercial applications and use of data as a source of novel services. Thus, essential elements to assess in business impact assessment are multi-actor perspectives and opportunities for sharing data, also outside the traditional partnership networks.

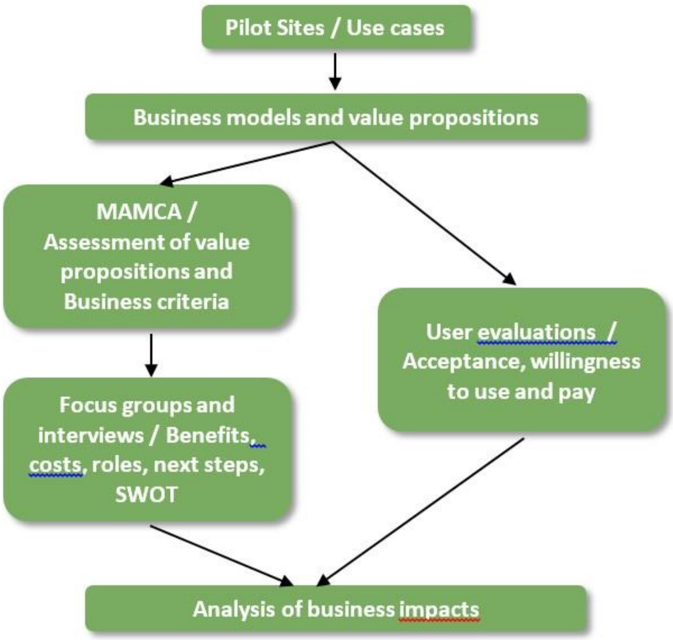

Fig. 4 - AUTOPILOT methodology for business impact assessment (modified from Nikolaou, 2018)

To focus on value creation, value proposition canvases were used in the project. Three value propositions were identified for Tampere AVP pilot:

1) Advanced parking management services (Business to business)
2) Park & ride in urban environments (Business to Public)
3) AVP Premium Ticketing Service (Business to (End-) Customer/ Consumer

The first steps of the business impact assessment process were to identify the stakeholder clusters, as well as the business impact criteria based upon which the evaluation, shown in Fig. 3 above, will be conducted, using the MAMCA methodology (De Brucker & Macharis, 2011). Three stakeholder events were held for assessing the service developed: A workshop in Tallinn with experts from UITP and 2 local workshops in Tampere.

The MAMCA process resulted in the highest ranking for the value proposition "Park & Ride in urban environments" of the three identified AVP value propositions. All stakeholder clusters that were represented in the workshops (industry, authority, research and users) assessed 'costs' as the most important criterion for this value proposition. The users cluster assessed equal weight to the criteria 'trust and acceptance'. In that respect, cost-related data is a priority, followed by the other business criteria (safety, economy, time and efficiency of travel, trust/acceptance, usability/user experience) that were selected in the MAMCA process.

Involved stakeholders emphasized that AVP is not only related to IoT but also to the potential ways in which infrastructure can be enhanced so as to enable this technology to support e.g. public transport and its passengers. They also stated that when designing parking areas, it is essential to consider all transport modes. Finally, they recommended not leaning on the technology itself, but also towards the design principles for the urban environment. The combination of the above will be beneficial for the platform, the operators and the passengers. However, it requires wide collaboration, establishing new value networks and developing new models for value creation.

In summary, the participants regarded IoT as an essential element for future traffic systems and mobility services, and thus business. The process will continue with input from the user evaluations, key (local where feasible) actors interviews and the conduct of the cost-related analysis, always in respect to the IoT technology and services brought to the AVP service. The full results of the business impact evaluation will be reported in December 2019.

5. Conclusions

Through IoT technologies the performance of automated driving services can be improved. The AUTOPILOT project has demonstrated the benefit of IoT for different use cases. In Tampere, both Automated Valet Parking and urban driving has been demonstrated. This paper describes the Automated Valet Parking service.

The urban driving use case in Tampere uses the same vehicle and traffic camera as in the AVP use case. But now the traffic camera monitors a pedestrian crossing, and verifies if pedestrians are crossing or waiting to cross, using a similar method as for detecting obstacles in the AVP service.

For the Automated Valet Parking use case, the user acceptance of the service has been tested with naïve test users. The majority of users found the service useful, and it would decrease their stress related to parking, but have concerns regarding data security and liability. The business opportunities of the service have been assessed with local stakeholders and the main obstacles to commercial deployments have been identified. Stakeholders regarded IoT as an essential element for future traffic systems and mobility services, and thus business.

The service allows also easier integration with other modes of transport, such as public transport, through providing Automated Valet Parking near public transport terminals, such as train stations: the driver drops the vehicle just before taking e.g long distance train to work, and in the evening the vehicle is delivered at the pick-up when the return train is arriving. The service is both useful for shared automated vehicles and for vehicles, owned by individuals. For shared vehicles, the service relieves end users of the need to look for parking spaces and could make it easier for shared car providers to guarantee vehicle availability at pick-up points.

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