

Automated Valet Parking enabled by Internet of Things: A pilot site realization and validation at Brainport, the Netherlands

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Helmond Automotive Campus**

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Introduction

Storyboard

- **Automated valet parking (AVP)** service where vehicles drive and park by itself



Step 1: Arriving at the drop-off position



Step 2: AUTOPILOT-APP requesting a parking spot



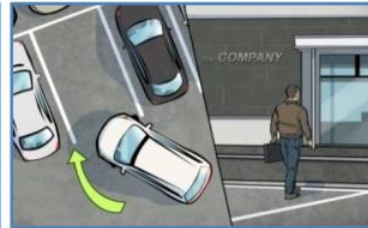
Step 3: Fixed cameras updating parking spot occupancy status



Step 4: Drone searches and confirms a free parking spot



Step 5: App displays the route to the parking lot

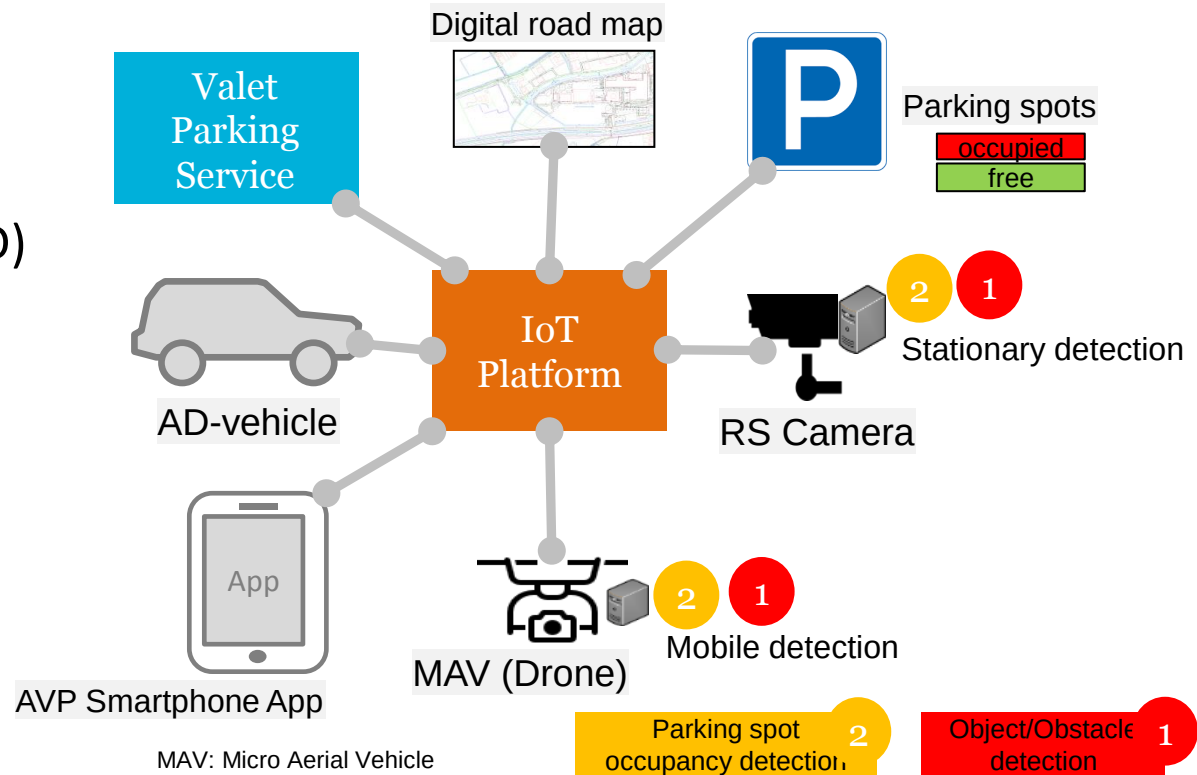


Step 6: Automated parking at the parking spot

AVP Implementation with IoT

- Bringing Internet of Things (IoT) to autonomous driving (AD) vehicles and advancing AD functionalities

→ Autopilot project



AVP IoT Architecture

- **AVP applications:** contains services such as parking management, user management and routing services
- **IoT platforms:** enables the IoT functionalities such as device management, context management, process and service management, semantics, analytics and security
 - IoT platforms' interworking gateway: Watson IoT and oneM2M IoT → **Platform Interoperability**
- **Things:** includes IoT devices such as AD vehicles, Roadside Unit (RSU) cameras, and MAV (Drone) and AVP smartphone App

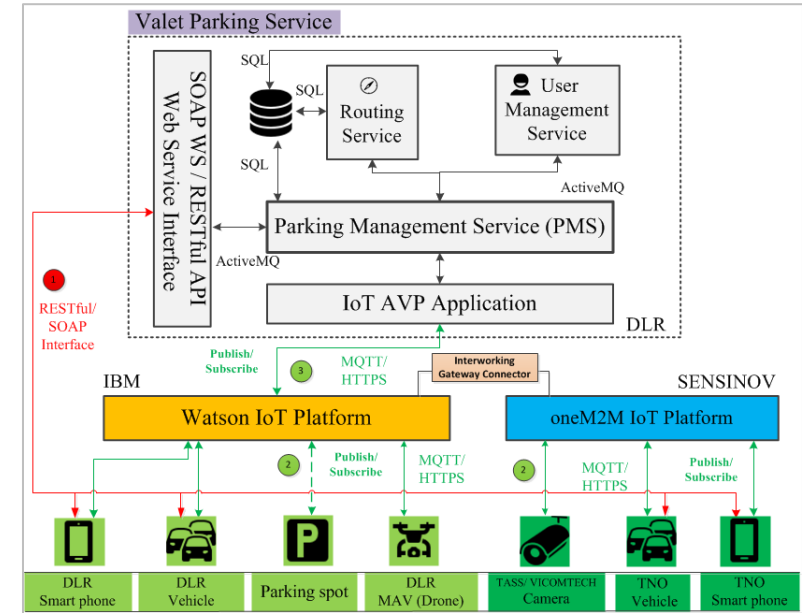
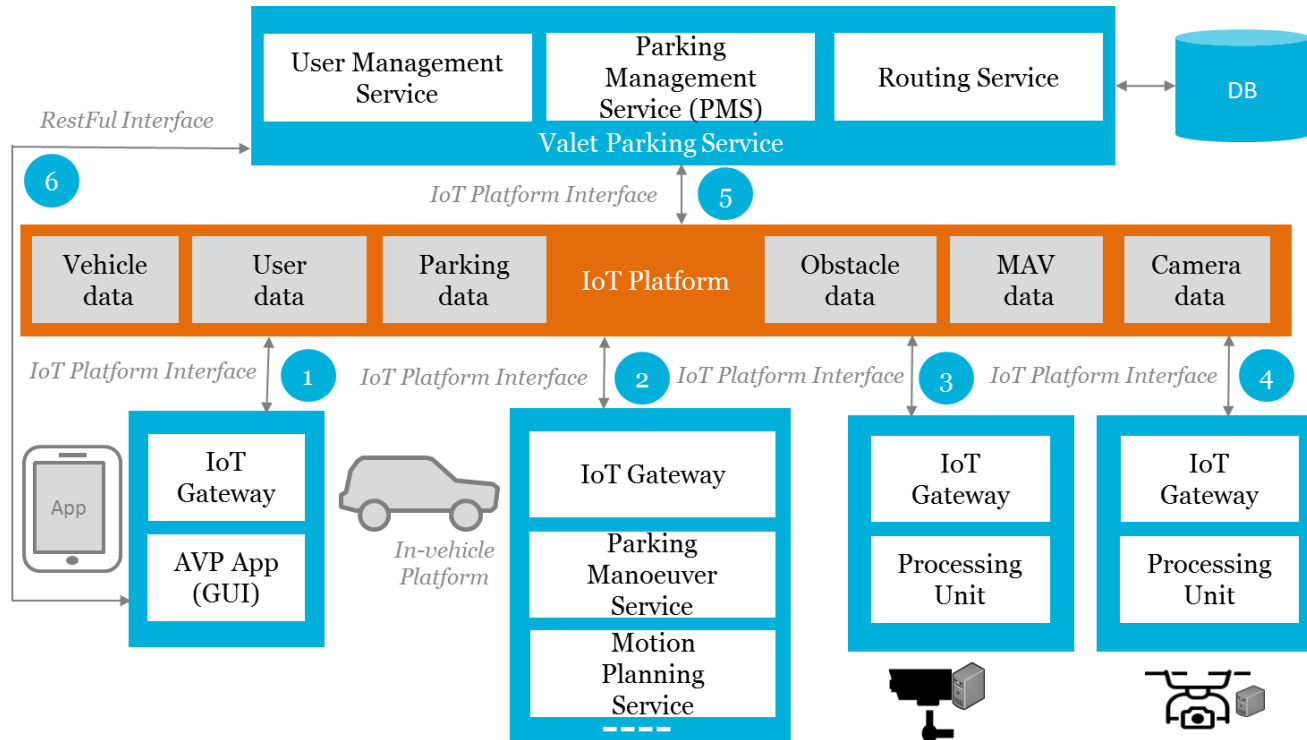


Figure: IoT system architecture of the automated valet parking use case in Brainport

IoT Communication Interfaces / IoT Data



AVP IoT Information Flow / IoT Event and Command Data

2. Vehicle IoT Command Data

- Park
- Collect

3. Vehicle IoT Event Data

- Status
- Position

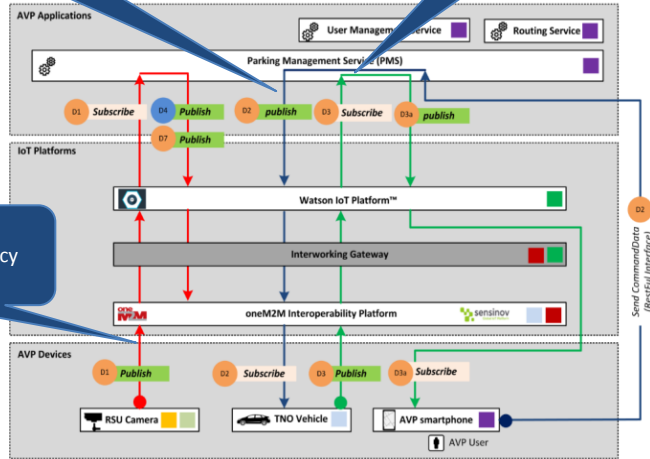
4&7. PMS IoT Event Data

- Parking spot occupancy
- Obstacle data

1. Camera IoT Event Data

- Parking spot occupancy
- Obstacle data

Automated Valet Parking (AVP) Use Case (I)

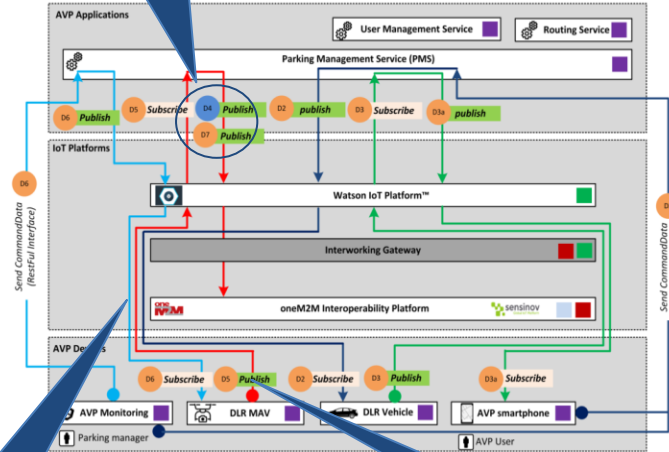


- TNO
- IBM
- DLR
- TASS
- Vicomtech
- Sensinov
- D1 Camera AVP Event Data
- D2 Vehicle AVP Command Data
- D3 Vehicle AVP Event Data
- D4 ParkingSpotOccupancyData
- D5 Obstacle Data
- Sensoris Data Model
- DATEXII Data Model

6. MAV IoT Command Data

- Fly

Automated Valet Parking (AVP) Use Case (II)



- TNO
- IBM
- DLR
- TASS
- Vicomtech
- Sensinov
- D5 MAV AVP Event Data
- D6 MAV AVP Command Data
- D7 Vehicle AVP Command Data
- D8 Vehicle AVP Event Data
- D9 ParkingSpotOccupancyData
- Obstacle Data
- Sensoris Data Model
- DATEXII Data Model

5. MAV IoT Event Data

- Parking spot occupancy
- Obstacle data

Vehicle Platforms – Adaptation of Autonomous Functions

- Two connected and automated vehicle prototypes from (DLR) and (TNO)



TNO / TASS + TUE
Toyota Prius



DLR's prototype Volkswagen e-Golf (FASCarE)

Figure: Connected and automated vehicle prototypes in Brainport pilot site

- Automation functions adaptation in vehicle to enable IoT autonomous driving
 - Radar and laser sensors, a differential GPS system for longitudinal and lateral control
 - An IoT gateway module
 - Software AD system: trajectory planning is based on optimal control
 - Human machine interface (HMI)

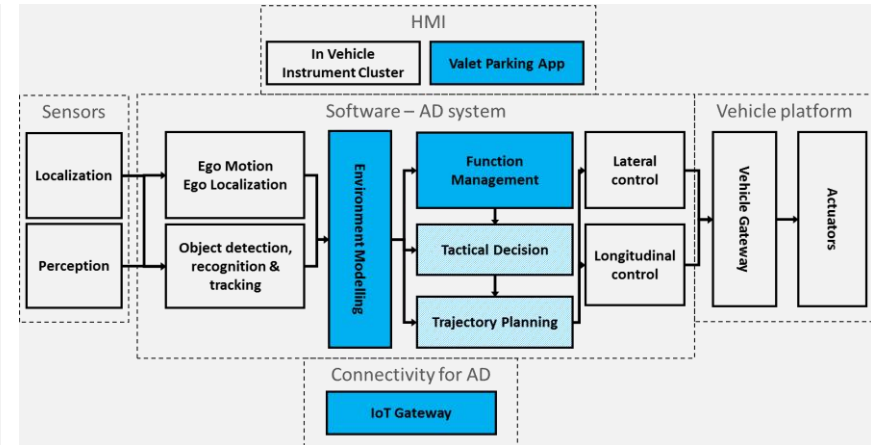
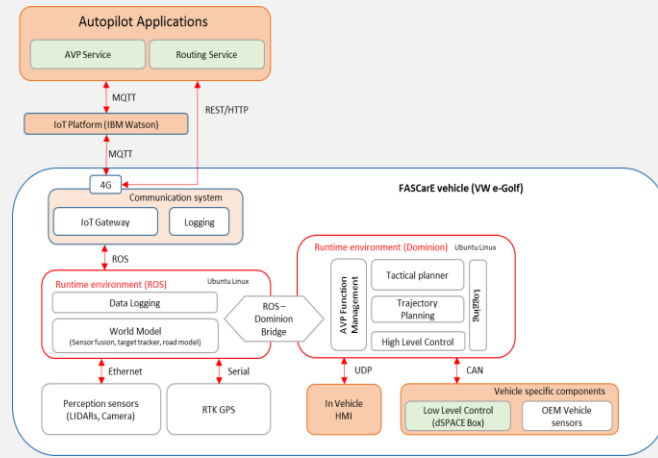


Figure : Adaptation of autonomous functions in DLR's vehicle prototypes

Vehicle Platforms - Integration of IoT Technology in Vehicle

• DLR vehicle

- Based on ROS and the proprietary DLR Dominion Environment IPC platform
- ROS for sensor fusion tasks, integrates the IoT client module
- Dominion Environment IPC platform for high frequency real-time control tasks and AD planning



• TNO vehicle

- Within the ROS-framework
- Sensors and actuators are over Ethernet or via a CAN-gateway
- AVP-application with functionalities: localization, object tracking, path planning, path tracking controller and IoT gateway

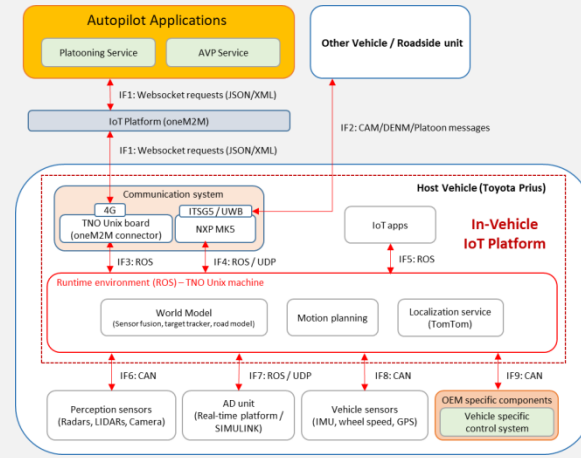
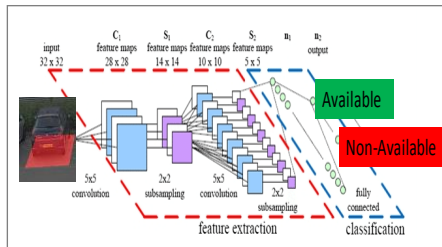
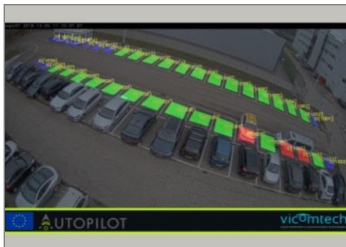


Figure: IoT software components architecture diagram of the DLR and TNO vehicles respectively

Free Parking Spot / Obstacle Detection

RSU Camera

- Tasks: to provide the status of parking spots and detections of static obstacles disabling any driving area
- Obstacle information is used by the routing service



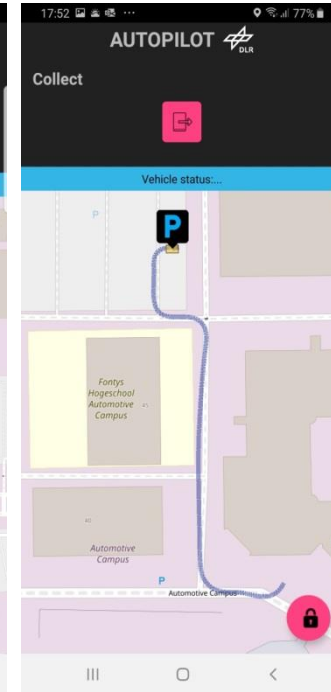
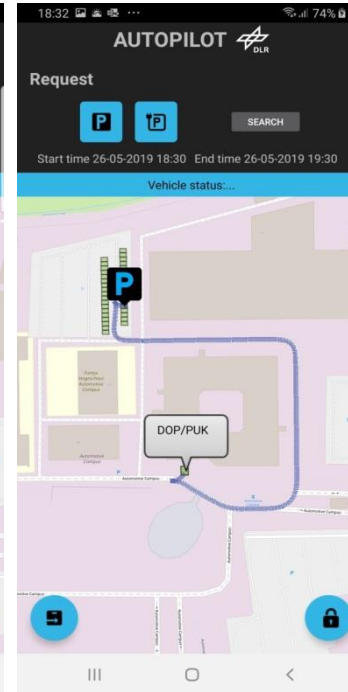
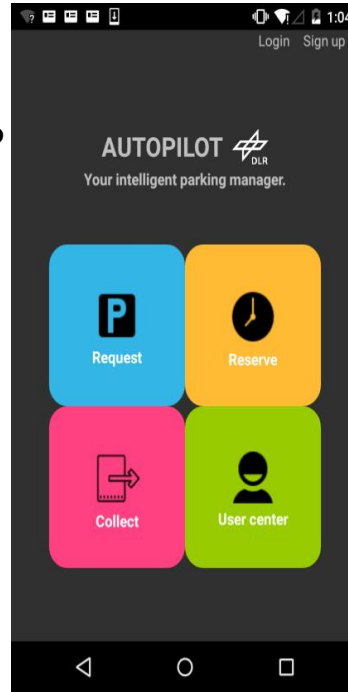
MAV (Drone)

- Equipped with two pairs of stereo cameras
- Workflow
 - Receiving the request IoT command to check the status of a particular parking spot from PMS
 - Flying to the parking spot and taking an image
 - Sending the image to a base station
 - Publishing results to the IBM Watson IoT platform
 - Flying back to the starting position



AVP IoT Mobile App

- Developed with Android API
- Consists of a SOAP web service interface and an IoT interface
- The integrated map is Open Street Map
- Support vehicle “Parking” and “Collection”



AVP Piloting and Technical Evaluation in Brainport - AVP pilot site

- Located at the Automotive Campus, Helmond
- Visitors leave the car at the drop-off point in front of the campus
- The car drives to the parking lot at the back of the campus and park there

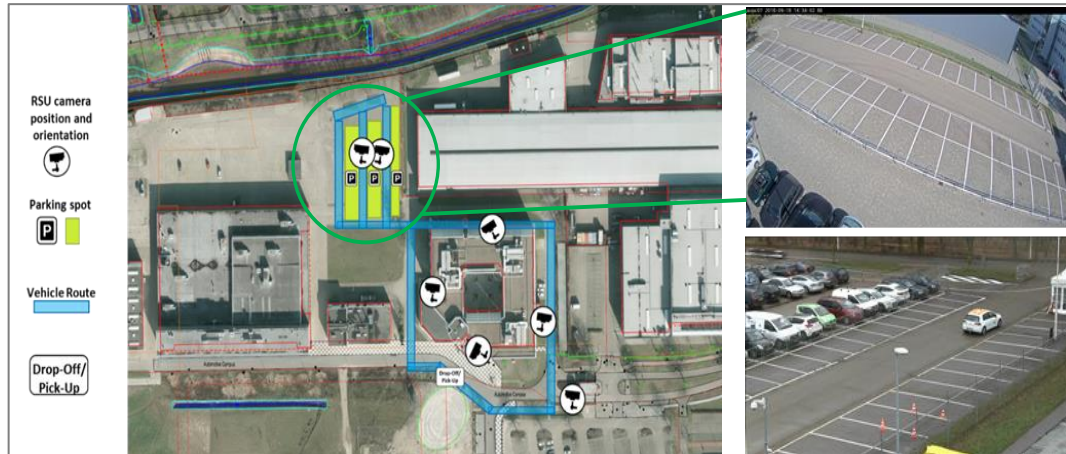


Figure: AVP test site and equipment at the pilot site Brainport

AUTOPILOT

The use of Internet of Things to enhance Automated Driving

The demonstration shows various technologies developed in the EU AUTOPILOT project for supporting automated driving with IoT enabled information and services. Through a combination of car platooning and automated valet parking the developments of several partners in the consortium will be addressed. Car platooning is demonstrated with two automated cars in real traffic through a live link, showing the formation process on-route from Helmond's city centre towards Eindhoven. One of the cars joins the platoon from the Automotive Campus, where it is collected from the parking using Automated Valet Parking. Once the formation has been achieved, the platoon speed will be adjusted to traffic light status and traffic congestion ahead that is detected, using IoT. The platoon returns to the Automotive Campus, where the demonstration seamlessly continues with Automated Valet parking.

Available parking spots are detected with IoT enabled camera systems (including one drone). The routes towards the parking will temporarily be obstructed, which is reported by vehicles that are driving on the routes report by a roadside camera system. One vehicle is equipped with pedestrian detection, and a second vehicle provides road hazard detection. The roadside camera system indicates the presence of other vehicles on the routes. Automated vehicles from several partners drive via the best route to the parking lot and perform various parking manoeuvres in automated driving mode. The parking is supported by a camera-equipped drone that flies fully automated. All involved systems are IoT connected to the parking service.



13th ITS European Congress

Please join the **live AUTOPILOT**
Automated Valet Parking (AVP)
Demo at the Automotive Campus
pilot site in Helmond.
June 4,5,6

Conclusion and Outlook

- Technical solution of the AVP enabled by IoT
- Seamless integration of multiple (IBM Watson and oneM2M) IoT platforms, multiple (DLR and TNO) AD vehicles, Smartphone Apps, MAV and RSU cameras into a valet parking service
- Piloting activities and technical tests confirmed the success
- Ongoing work is to improve the user experience

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<http://autopilot-project.eu/>

AUTOated driving **P**rogressed by **I**nternet **O**f **T**hings



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Thank you for your Attention & Questions