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Internet of Things (IoT) for autonomous driving in case of Automated Valet Parking (AVP)

Dipl.-Ing. Louis Touko
German Aerospace Center (DLR)
Institute of Transportation Systems
www.dlr.de/en

DLR

AUTOPILOT (AUTOMATED DRIVING PROGRESSED BY INTERNET OF THINGS)

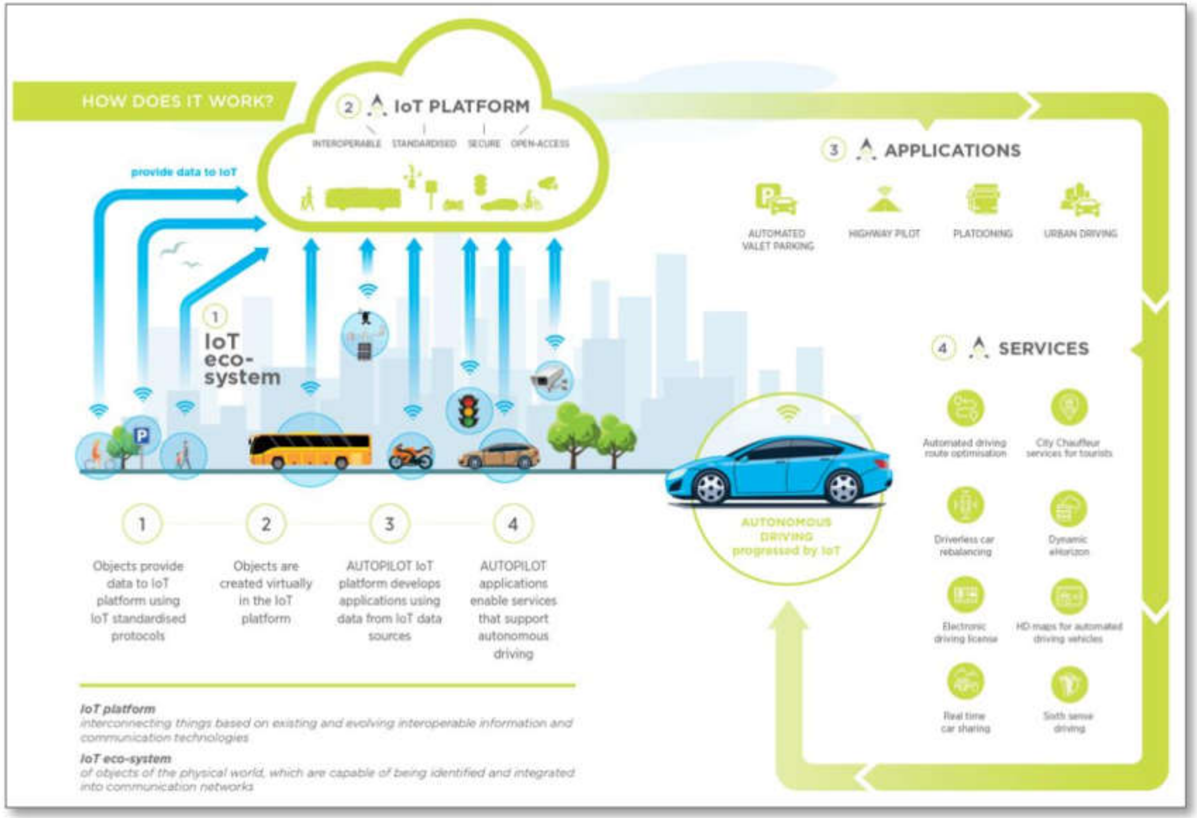
European Large-Scale Pilot (LSP) Project

- Coordinator: ERTICO-ITS Europe (BE)
- Website: www.autopilot-project.eu
- Duration: 01.2017- 02.2020
- 6 Pilot sites
- Participant: more than 45 partners from15 different European countries

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731993

IoT in AUTOPILOT: the benefits

- IoT allows to extract information that is beyond the reach of sensors; it puts data in context, including its reliability, and it connects anything as a source. AUTOPILOT aims at creating an eco-system that exploits the potential of IoT for automated driving, while also making data from autonomous cars available to the Internet-of-Things;
- By bringing IoT into the automated driving world, AUTOPILOT will speed up the transformation of connected vehicles into highly and fully automated vehicles;
- AUTOPILOT harnesses the potential of IoT to improve in particular safety-critical aspects of automated driving;
- IoT improves automated driving by enhancing existing functions, e.g. anticipation increases the level of comfort and confidence for the driver;
- IoT (connecting anything, anytime, anywhere, using any service over any network) will open up automated driving to new business opportunities, enabling new AD functions and new mobility service.



The AUTOPILOT Overall concept

AUTOPILOT (AUTOMATED DRIVING PROGRESSED BY INTERNET OF THINGS)
Overview of use cases and pilot site location

5 AUTOPILOT Uses Cases:

- **Urban driving**
  - Versailles (FR), Brainport (NL), Vigo (ES), Livorno (IT), Tampere (FI), Daejeon (KR)
- **Automated valet parking**
  - Brainport (NL), Vigo (ES), Tampere (FI)
- **Highway pilot**
  - Brainport (NL), Livorno (IT)
- **Platooning**
  - Versailles (FR), Brainport (NL)
- **Car sharing**
  - Versailles (FR), Brainport (NL)

6 AUTOPILOT Pilot Sites:

AUTOPILOT

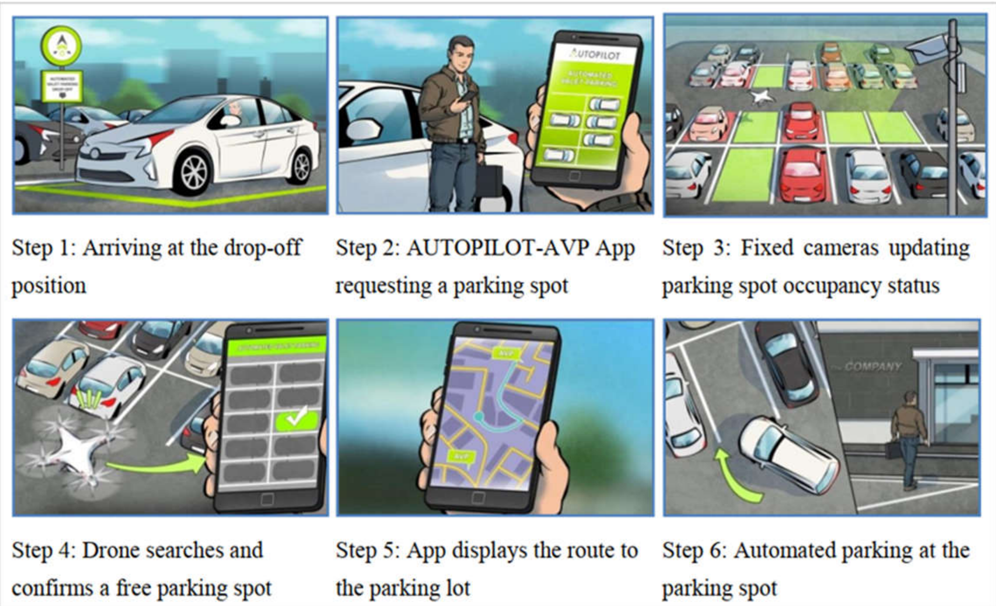
Use case: Automated valet parking - Brainport (NL)

Domain application areas addressed

Automated Valet Parking (AVP) is a driverless Automated Driving use case including on-street car drop-off, driving to and from a parking spot, forwards and backwards manoeuvring as well as on-street passenger pick-up. IoT functions include routing, localization of obstacles and even control decision making at the IoT Edge.

Short description and location

In the Automated Valet Parking (AVP) use case, the driver is able to leave the car at some predefined drop-off location and is able to retrieve it once he/she needs it back. The operations of parking and manoeuvring the car in the parking area (inside or outside) and retrieving it are managed by the parking management system and supported by a Micro Air Vehicle (MAV) Brainport (NL).



Step 1: Arriving at the drop-off position

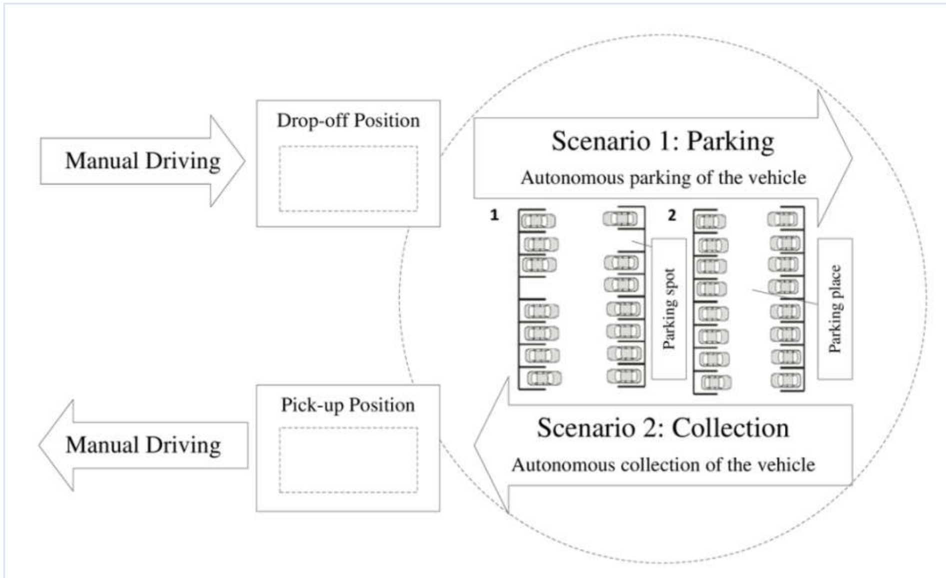
Step 2: AUTOPILOT-AVP App requesting a parking spot

Step 3: Fixed cameras updating parking spot occupancy status

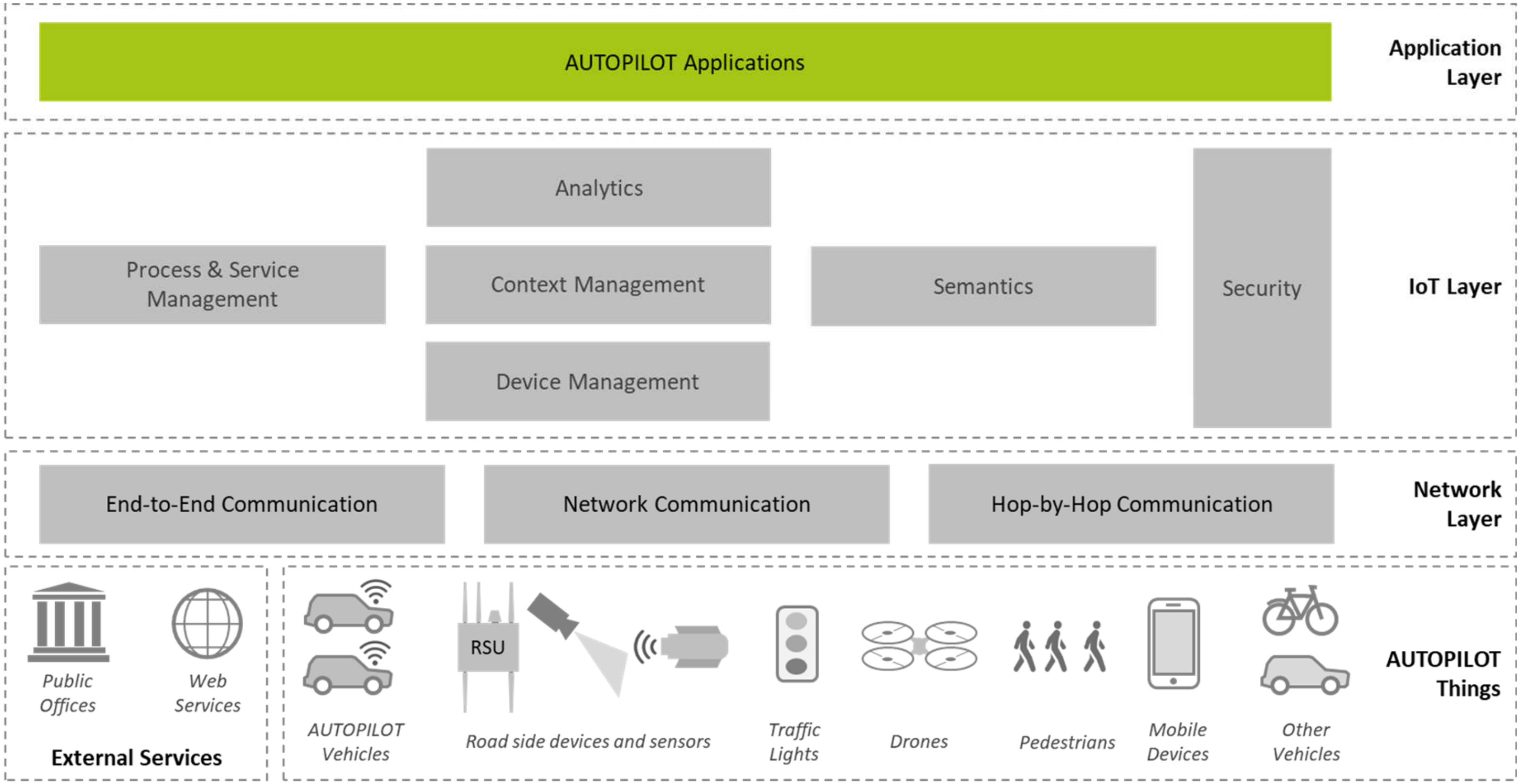
Step 4: Drone searches and confirms a free parking spot

Step 5: App displays the route to the parking lot

Step 6: Automated parking at the parking spot



IoT Architecture: Functional View

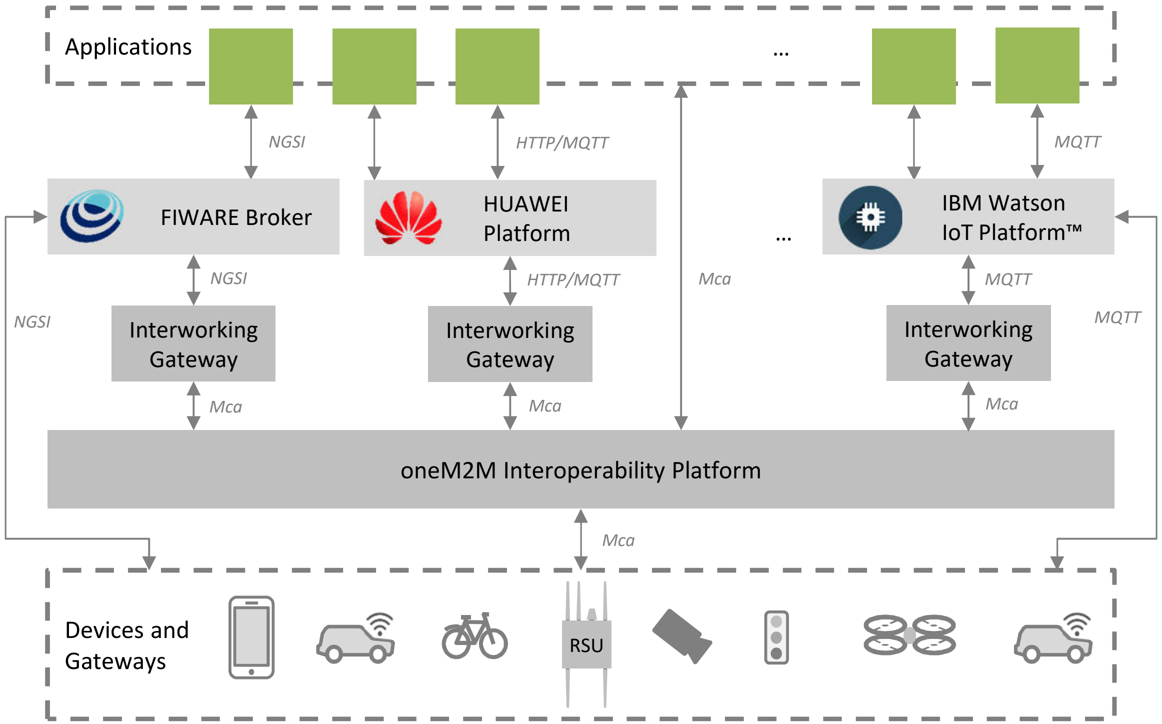


AUTOPILOT Federated IoT Architecture

Devices, gateways, and in-vehicle and road-side IoT platforms exchange information (e.g., about detected objects, hazards, vulnerable road users, traffic lights, vehicle updates) with several distributed cloud IoT platforms.

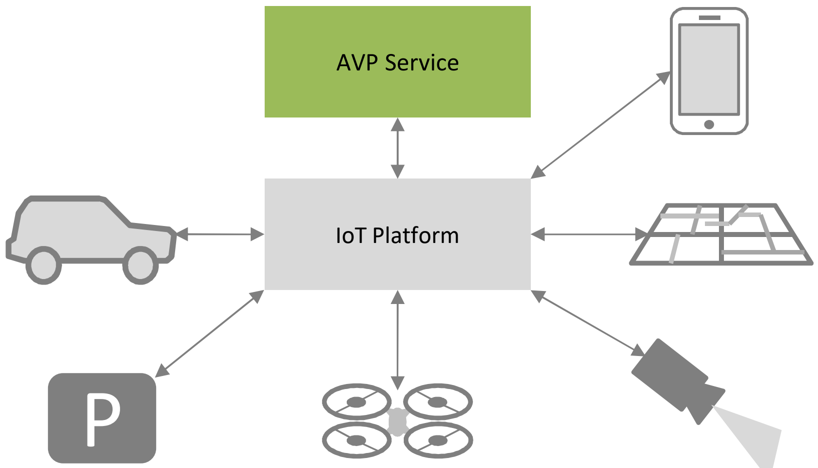
- There are two types of cloud IoT platforms:
  - Proprietary IoT Platforms
  - oneM2M Interoperability Platform

- Interoperability in AUTOPILOT is achieved based on the following key concepts:
  - **oneM2M Standards**
  - **Standardized IoT data models**
    - Based on DATEX II and SENSORIS
  - **Standardized ontologies**



Example: Automated Valet Parking Implementation (1)

Conceptual View

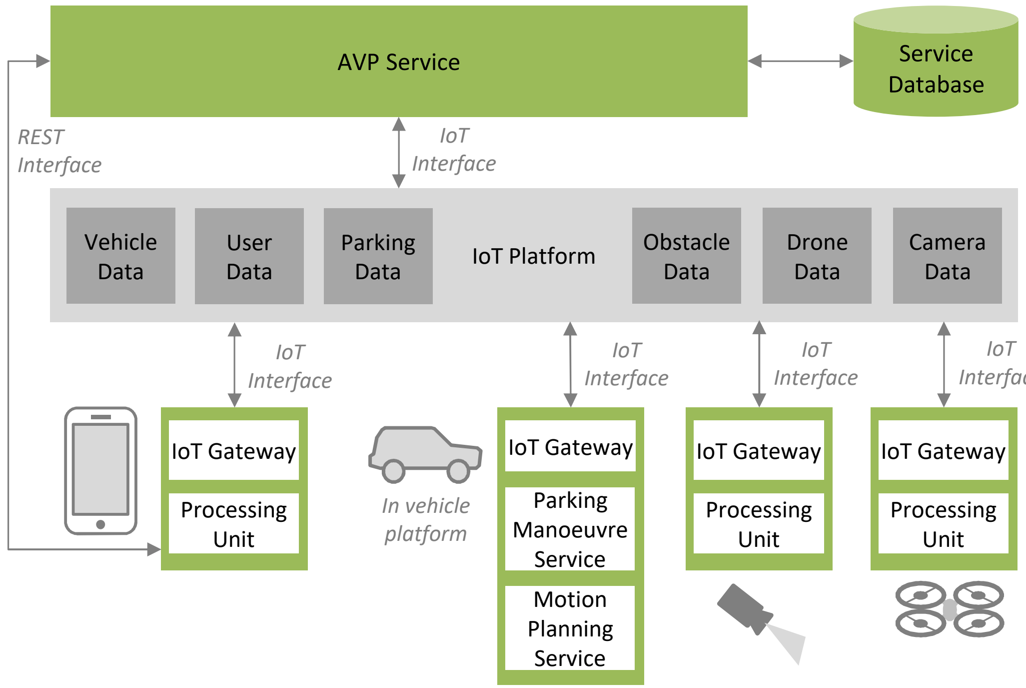


Parking spots
- Occupied
- Free

Mobile Detection
- Parking spot occupancy detection
- Obstacle detection

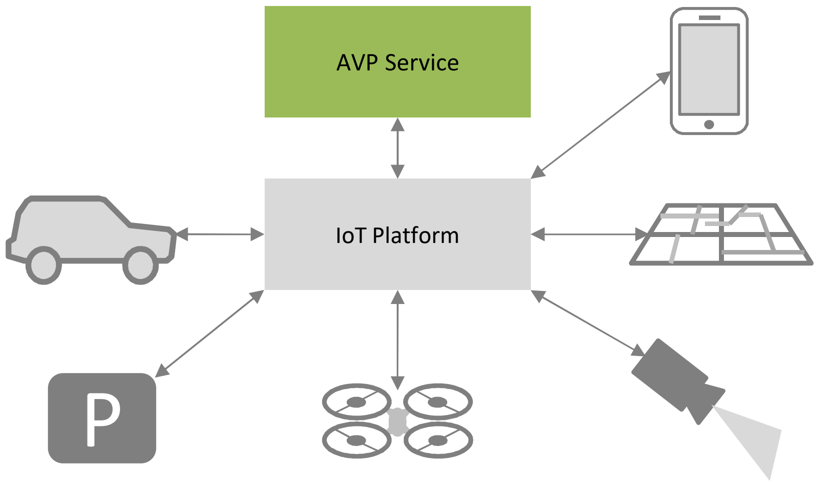
Stationary Detection
- Parking spot occupancy detection
- Obstacle detection

IoT Communication View



Example: Automated Valet Parking Implementation (2)

Conceptual View



Parking spots
- Occupied
- Free

Mobile Detection
- Parking spot occupancy detection
- Obstacle detection

Stationary Detection
- Parking spot occupancy detection
- Obstacle detection

System Architecture View

Involved partners

DLR, TNO innovation for life, vicomtech, sensinov, IBM, National Electric Vehicle Sweden, NEVS, Gemeente Helmond, SIEMENS Ingenuity for life

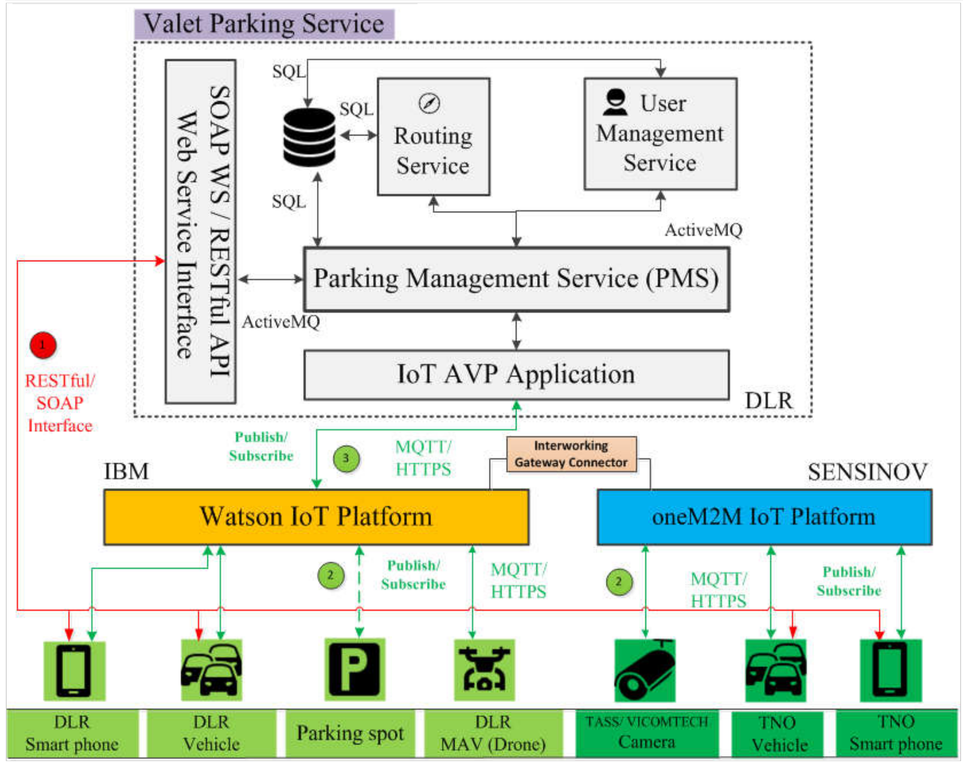


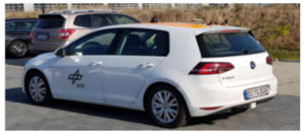
Figure: IoT system architecture of the automated valet parking use case in Brainport

AVP Vehicle Platforms

Adaptation of autonomous functions / Integration of IoT technology in vehicle

Adaptation of autonomous functions

TNO / TASS + TUe Toyota Prius



DLR‘s prototype Volkswagen e-Golf (FASCarE)

NEVS‘s prototype

Figure: connected and automated vehicle prototypes

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)

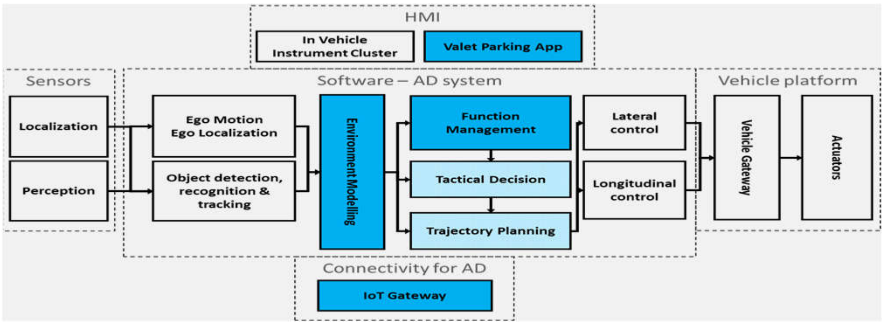


Figure: Adaptation of autonomous functions in DLR’s vehicle prototypes

Integration of IoT technology in vehicle

- **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

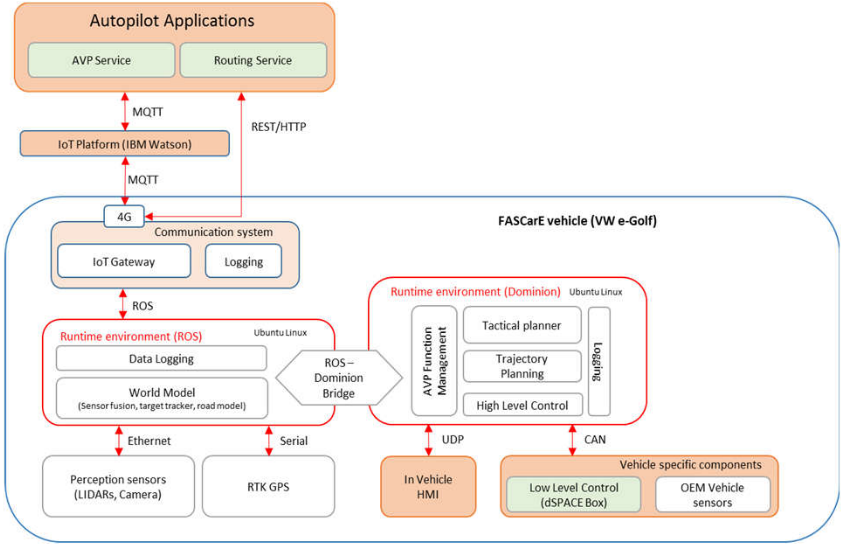


Figure: IoT software components architecture diagram of the DLR

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Road Side Unit (RSU) camera
Stationary detection

- RSU-Camera are installed on the parking area and the driving area and act as **IoT devices**
- **Tasks:** to provide the status of parking spots and detections of static obstacles disabling any driving area
- **Free parking spot detection**
  - Localization of parking spots
  - Classification of parking spots to determine if they are occupied or available using a convolutional neural network (CNN)
- **Static obstacle detection**
  - Information including its GPS location → IoT platform
  - Notify the obstacle removing

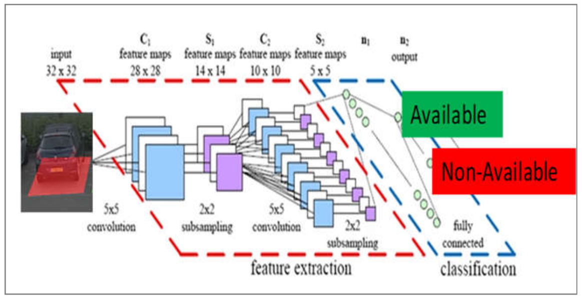


Figure: AVP road unit camera and parking lot detection visualization

Micro-Aerial Vehicle (MAV) / Drone
Mobile detection

- MAV and ground-station PC act as IoT device
- **Tasks:** observe the status of particular parking spots
- **MAV configurations:** Custom coaxial tricopter designed by DLR and equipped with two pairs of stereo cameras providing approximated 240° vertical field of view

- **Workflow**
  - Waiting for a command from the parking management system at its starting position
  - Receiving the request to check the status of a particular parking spot
  - Flying to the parking spot and taking an image
  - Sending the image to a base station
  - Sending results to the IBM Watson IoT platform
  - Flying back to the starting position

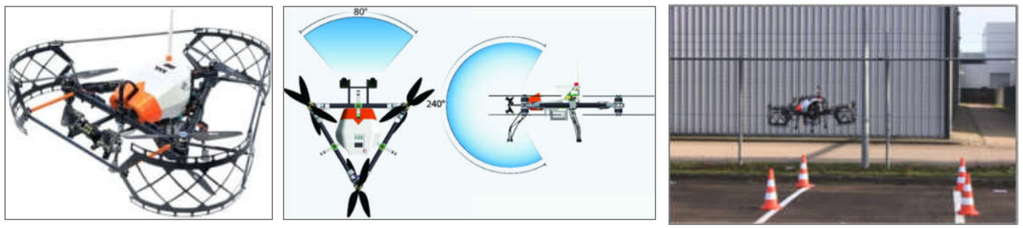
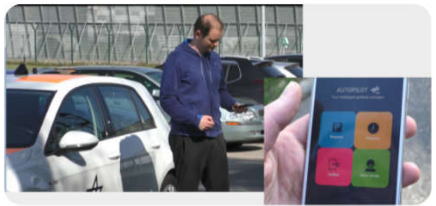
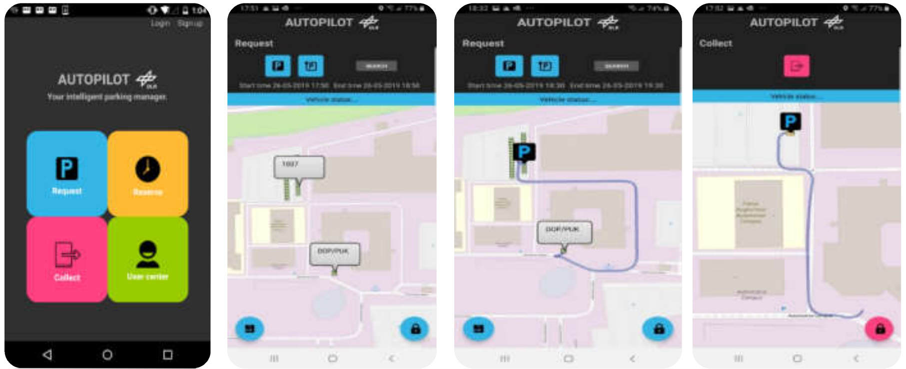


Figure: MAV and stereo camera setup and field of view

AVP Smart Phone Application
Mobile App

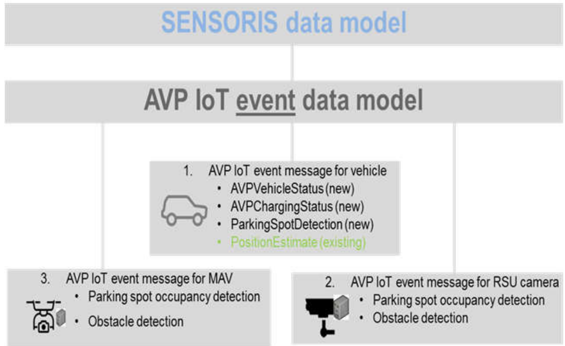
- Developed with Android API
- Consists of SOAP web services and IoT interface
- Supports vehicle “**Parking**” and “**Collection**” scenarios
- Provides information about the valet parking process to the user.



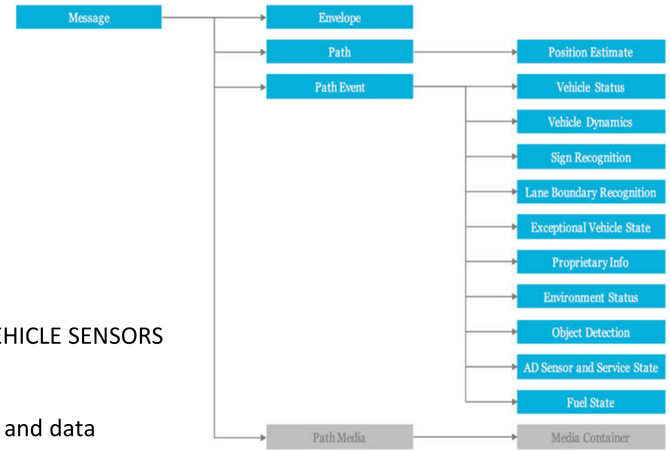


AVP Data Models

- AVP data model consists of
  - **IoT Event data models**
    - Standardized SENSORIS data model has been extended to support information specific to AVP
    - MAV and RSU camera data models are based on SENSORIS data model
  - **IoT Command data models**
    - to model the command message for vehicle and MAV



Example of AVP vehicle IoT event message "PositionEstimate"



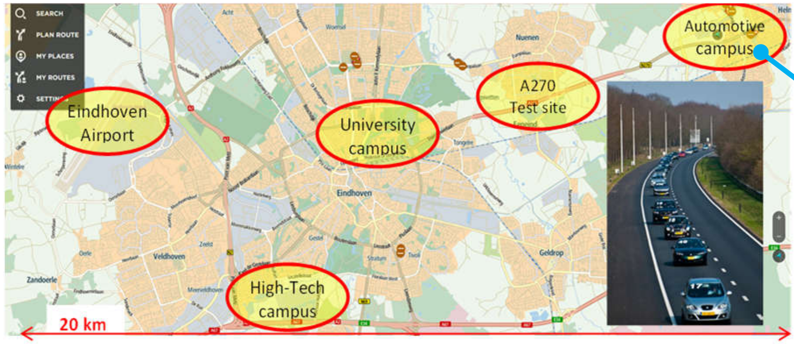
Overview of the SENSORIS Message Elements

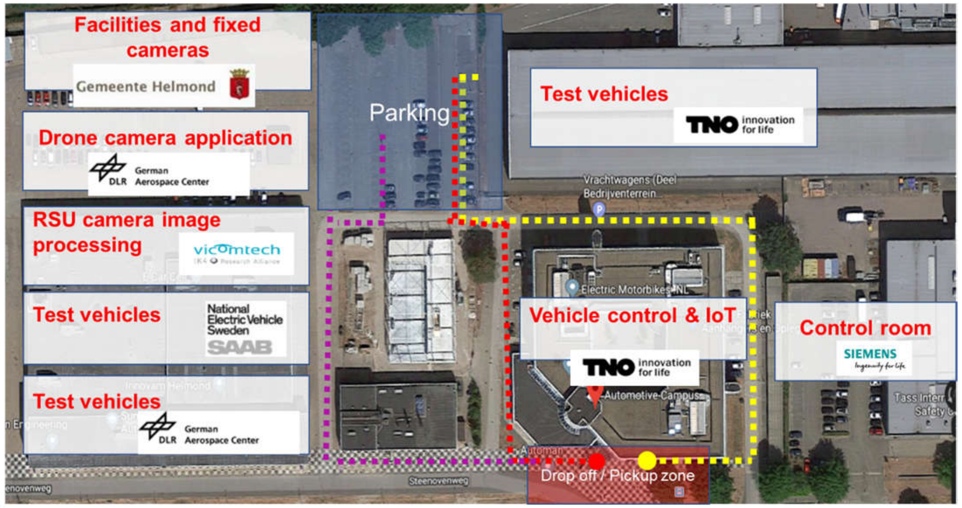
SENSORIS:

- Sensor Interface Specification
- A GLOBAL STANDARDISED INTERFACE TO EXCHANGE INFORMATION BETWEEN IN-VEHICLE SENSORS AND A DEDICATED CLOUD, AS WELL AS BETWEEN CLOUDS
- Managed by ERTICO – ITS Europe
- SENSORIS represents a group of 28 key players from the global vehicle industry, map and data providers, sensors manufacturers and telecom operators
- https://sensoris.org/

AVP Piloting & Demonstration in Brainport

Test location: Automotive Campus, Helmond (NL)





AVP test site and equipment in the pilot site Brainport

AVP Demonstration in Brainport

Test location: Automotive Campus, Helmond (NL)

- AVP Use Case has been tested and successful demonstrated at the 13th ITS European Congress in Helmond (NL, June 2019) and at the final event in Versailles (FR, February 2020)

AVP Technical Evaluation
Test location: Automotive Campus, Helmond (NL)

- The car is enabled through **IoT** to drive unmanned to a parking spot, and to return to the driver on command
- This offers:
  - Comfort service to car drivers (no time lost finding a parking spot)
  - More efficient use of space on parking lots (cars can be parked closer)
  - Less damage to cars during parking
  - Optimization of logistics and reducing congestion in and towards parking area
  - More efficient use of EV charging spots

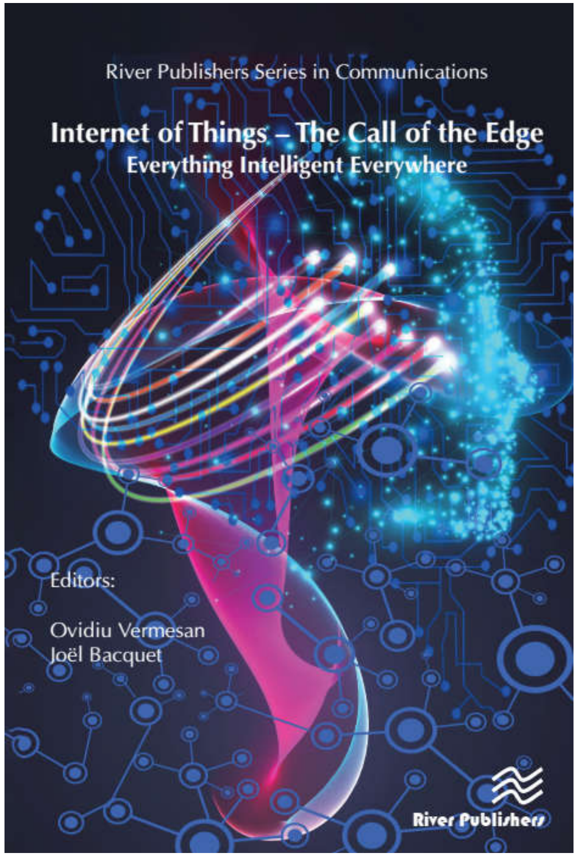
KPI: Key Performance Index

No.	KPI	Measurement	Description
KPI-1	Parking duration	seconds	**Drop-off scenario:** Time from drop-off point until vehicle is parked (parking spot). **Pickup scenario:** Time from parking spot until the vehicle reached the pickup point.
KPI-2	Detection performance of free parking spots (Parking spot occupancy)		**RSU Camera** 1) **Detection performance of free parking spots:**
KPI-5	Reliable information of the driver about the parking process	duration	Delay between the message transmission from the message generation in the vehicle to the message reception at the AVP mobile APP interface
KPI-6	Detection performance of **object/obstacle** on the road		manually, correctness of the object detection through the AV-vehicle or RSU camera **RSU Camera** **Detection performance of obstacle detection I the danger area.**
KPI-7	Parking		Evaluate if the cars are parking 100% of the times properly and never cause damages during the test scenario
KPI-8	Technical complexity of the implementation		Evaluate the technical complexity of the implementation, also analysing the different cases (outdoor / indoor)

No.	Topic	Research Questions	Hypotheses	KPI
1	Time saving	Can the system decrease the time a user needs to park their car?	Since the user does not need to be present during the parking maneuver, less time will be required.	KPI-1
2		Can the system reduce the total parking maneuver time?	The total time of the parking maneuver is less with the AVP system than driving manually.	KPI-1
3	Safety	Does the AVP system improve user security?	Since the user does not need to be present during the parking maneuver, it is impossible for him to suffer any damage during it.	KPI-2
4		Does the AVP system improve pedestrians' security?	Since the autonomous parking area will be isolated, there will be no users in it reducing the risk of accident.	KPI-2
5		Does the AVP system improve VRU security?	The IoT will allow the detection of VRU before it enters the range of the car's sensors, allowing the system to react earlier.	KPI-2
6	Energy efficiency	Is the energy consumption reduced when using the system?	The reduction of time and optimization of routes will cause a reduction in consumption.	
7	Maneuver precision	Can the AVP system carry out the parking maneuver with the same or higher precision than that obtained manually?	The system is accurate enough not to compromise the integrity of the vehicle.	KPI-7
8	Maneuver information	Does the user have real time information during the maneuver even though he is not present?	The app informs the user in real time of the state of the vehicle during the maneuver.	KPI-5

Useful Links …

- Book: **Internet of Thinks - The Call of the Edge**. Everything Intelligent Everywhere
  - ISBN 978 877 022 196 2
  - https://www.riverpublishers.com/pdf/ebook/RP_E9788770221955.pdf
  - Chapter 6: IoT Technologies for Connected and Automated Driving Applications.



- AUTOPILOT Project web page
  - https://autopilot-project.eu
  - Deliverables
  - https://autopilot-project.eu/deliverables

Thanks for you attention!

Dipl.-Ing. Louis Touko

Research Scientist

German Aerospace Center

Institute of Transportation Systems

Web page:
http://www.DLR.de/en

Address:
Rutherfordstr.2, D-12489 Berlin, Germany

E-Mail:
Louis.ToukoTcheumadjeu@DLR.de

Phone:
+49 3067055 284

Brainport Pilot Site (NL)