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Automated Valet Parking enabled by Internet of Things(IoT) Brainport Pilot Test

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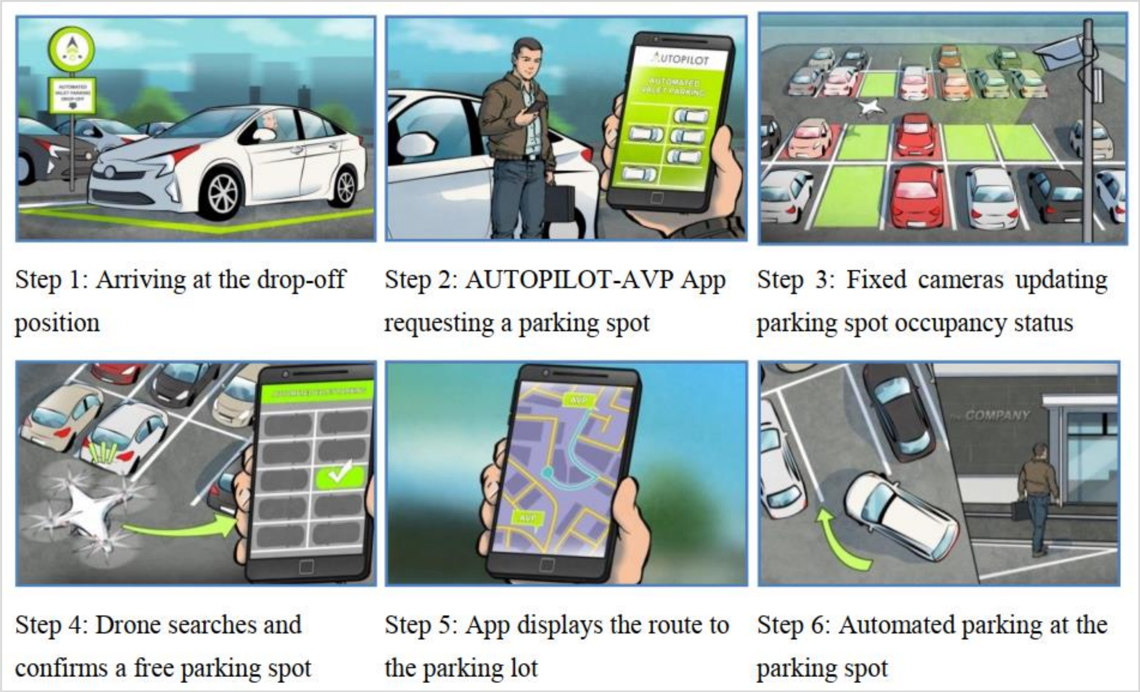
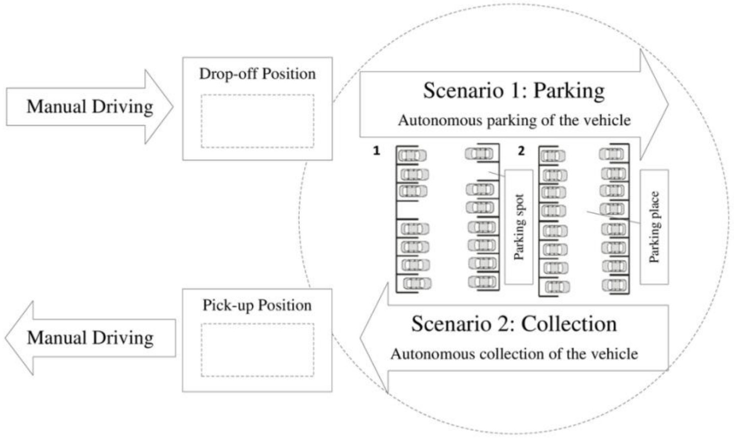
AVP Storyboard

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

The car is enabled (through IoT) to drive autonomously

- from the **drop-off** (DO) point to a parking spot **(parking scenario),**
- and to return to the **pickup** (PU) point (**collection scenario**) to the driver on command using mobile App

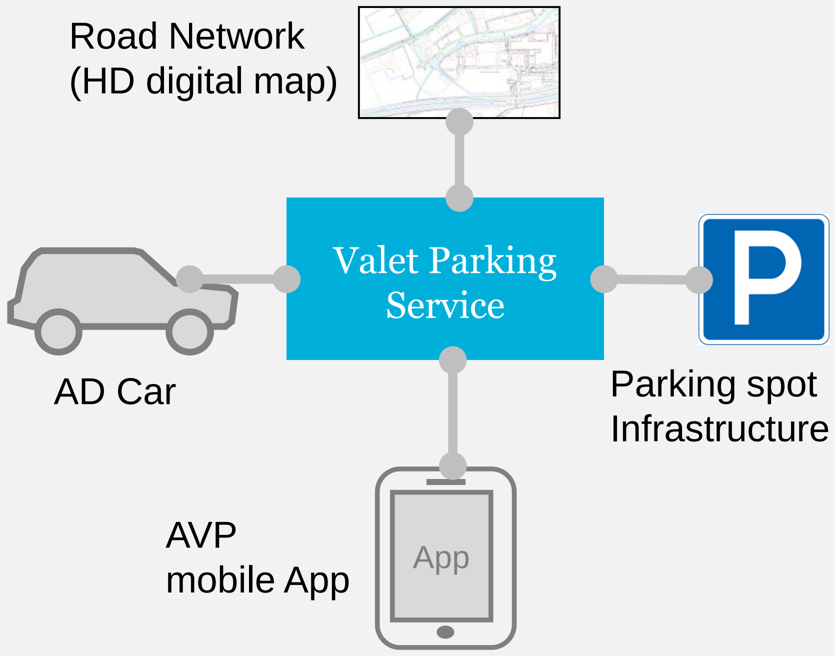




AVP Implementation

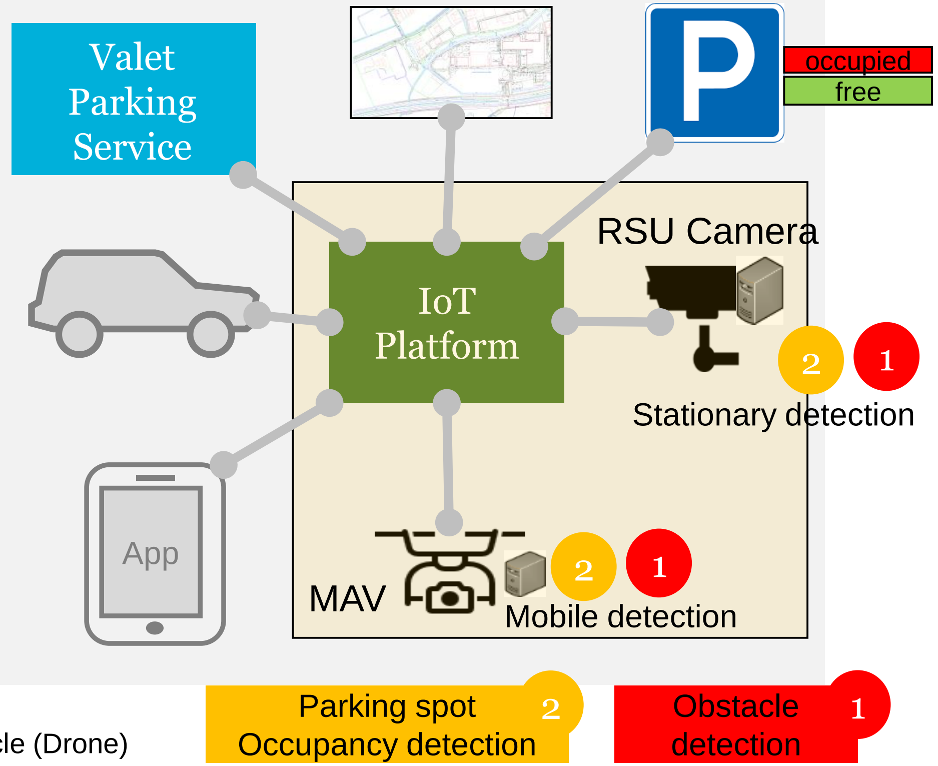
Option 1: **without** IoT

- Parking spot exploration is needed



Option 2: **With** IoT

- No need of parking spot exploration



- IoT **concept** of AVP development
- IoT **Interface** implementation on the IoT devices and application side to allow the communication with the IoT platform
- IoT (standardized) **data model** specification for all involved IoT devices (vehicle, MAV, RSU camera, etc..)
- Adaptation of **automation functions** in the vehicle to support IoT data
- Define the **communication workflow** between system components

MAV: Micro Aerial Vehicle (Drone)

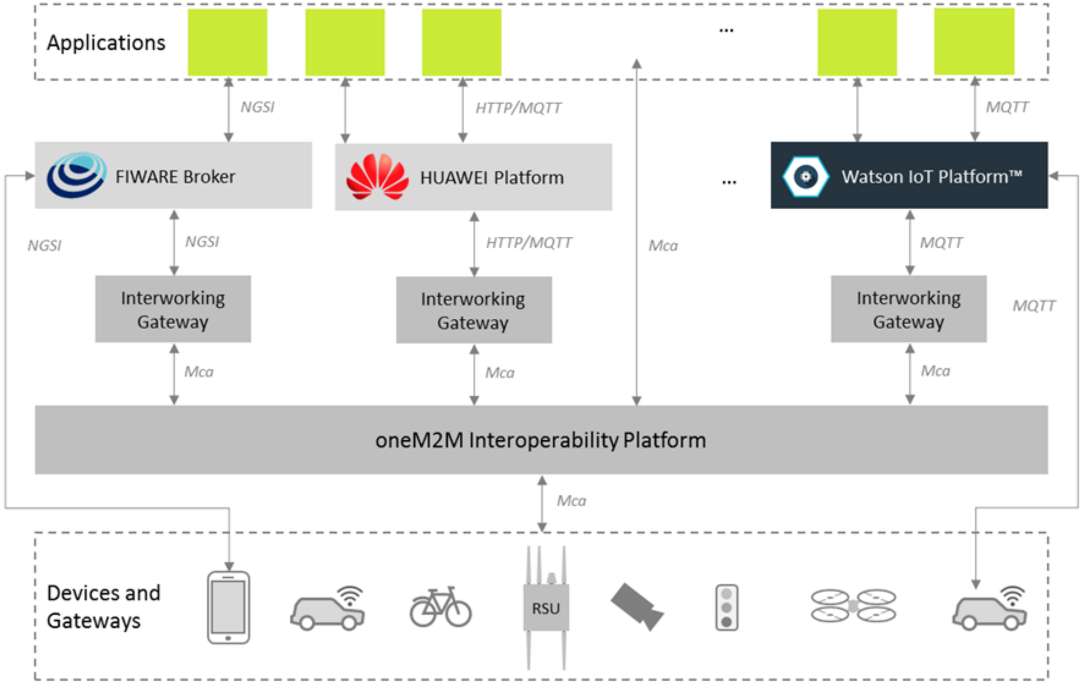
IoT + 5G

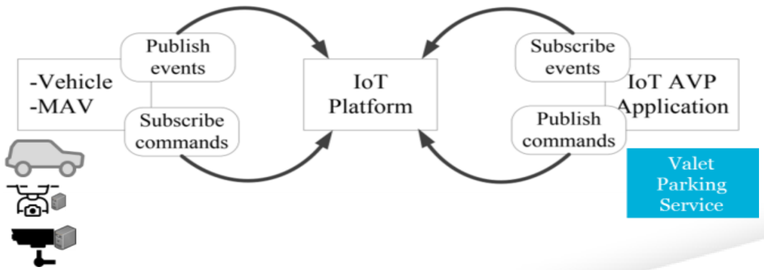
IoT Technology and Autonomous Driving

AUTOPILOT Project: Bringing Internet of Things (IoT) to autonomous driving (AD) vehicles and advancing AD functionalities

- **Devices:** IoT vehicle, IoT smartphone, MAV equipped with cameras
- **Actions of application:** publish events/commands to the IoT platform, subscribe events/commands
- **Actions of devices:** publish events to the IoT platform, subscribe commands
- **Action of Platform:** acts as broker**,** receives and manages information from IoT devices and applications, provides the information to the data subscriber.

AUTOPILOT Federated IoT Platform Architecture





AVP IoT based System 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

Involved partners

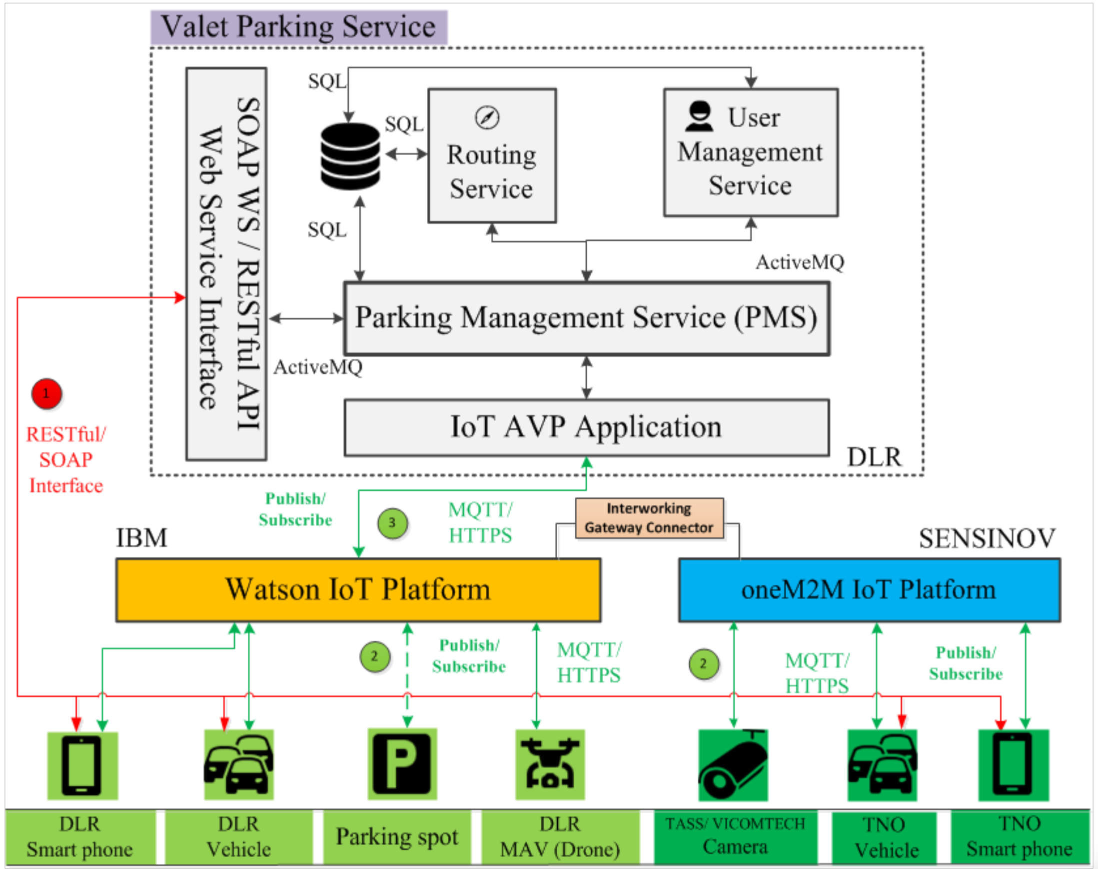
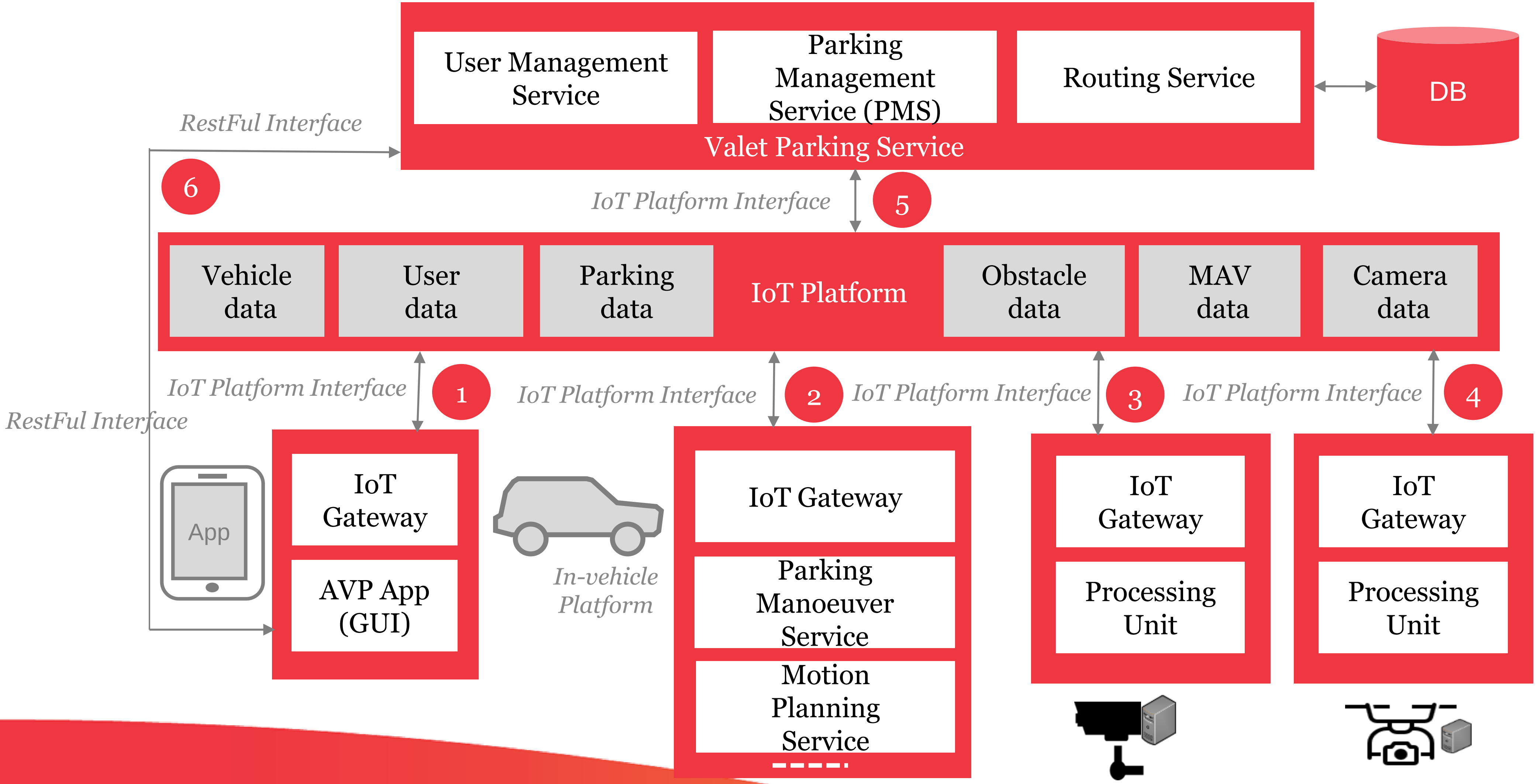


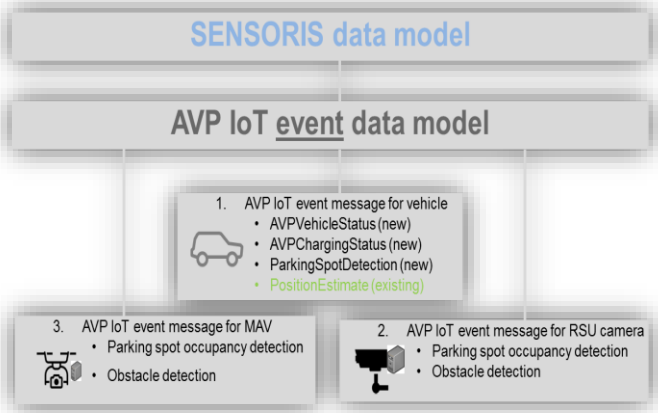
Figure: IoT system architecture of the automated valet parking use case in Brainport

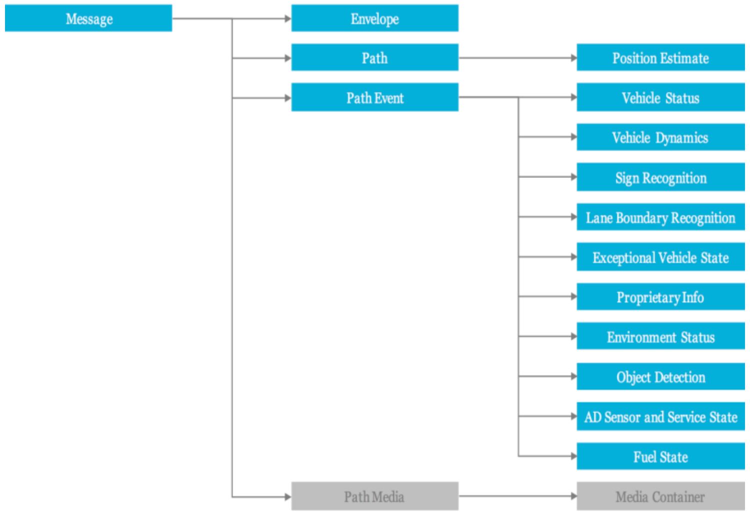
System components and IoT Communication Interface



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





Overview of the SENSORIS Message Elements

Example of AVP vehicle IoT event message "PositionEstimate"

AVP Vehicles Platforms

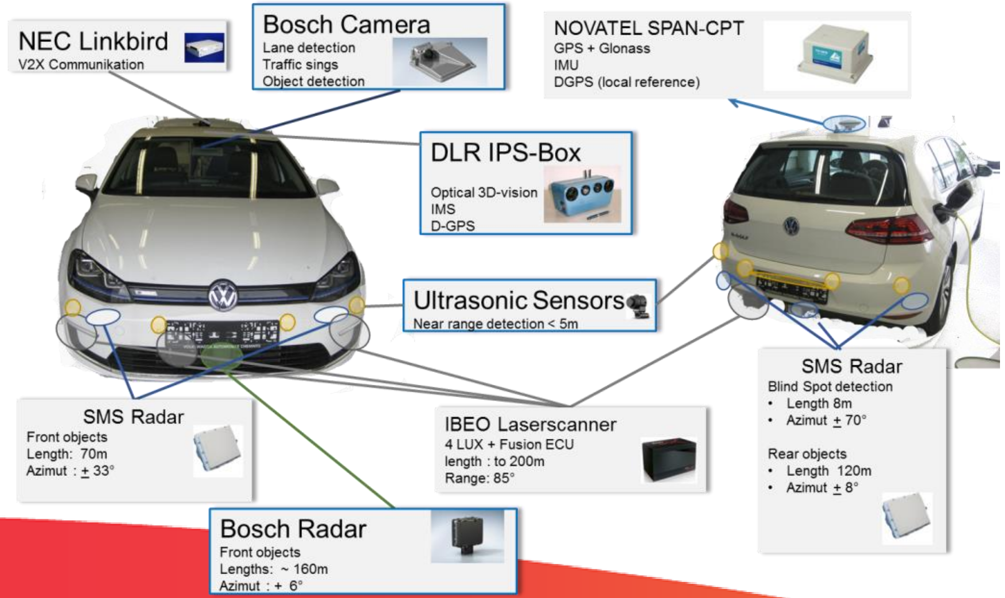
Connected / Automated Vehicle Prototypes

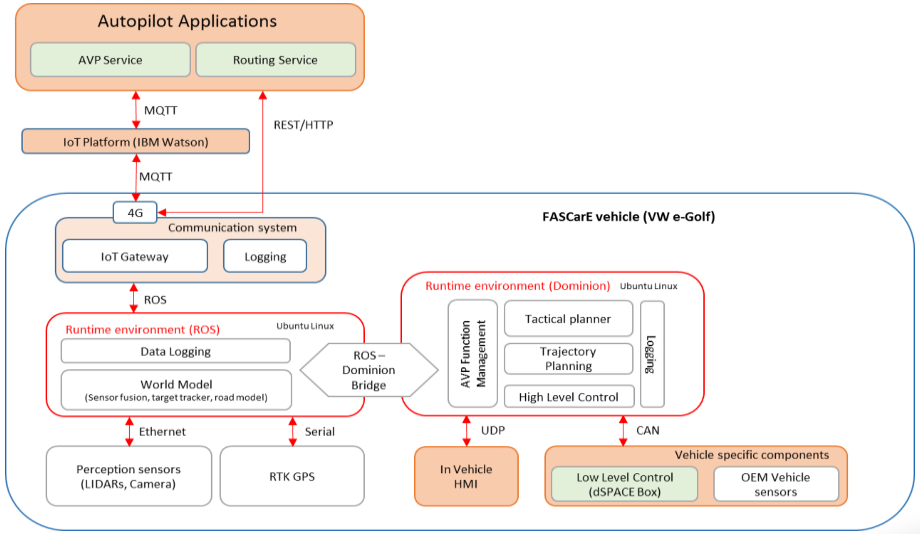
PS Brainport:
TNO / TASS + TUE Toyota Prius

PS Brainport:
DLR's prototype Volkswagen e-Golf

PS Brainport:
NEVS's prototype

DLR vehicle sensors





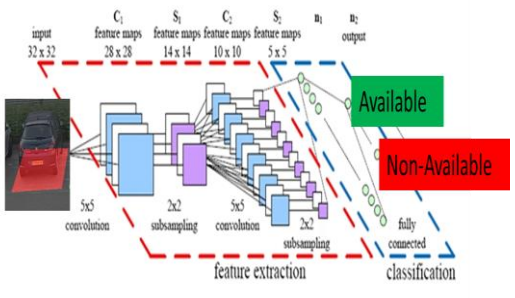
IoT software components architecture diagram of the DLR vehicle

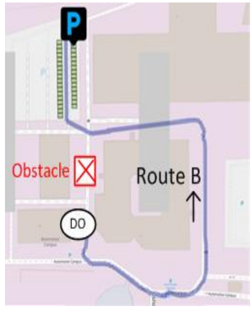
RSU-Camera Application
Stationary Detection

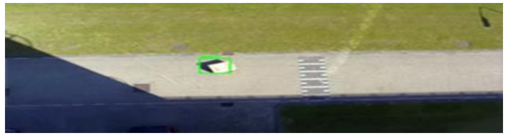
Free parking spot and obstacle detection

- RSU-Camera are installed on the parking area and the driving area and act as IoT devices
- **Task:**
  1. To provide the status of parking spots and detection of static obstacles (PEDESTRIAN, VEHICLE, BICYCLE …) disabling any driving area
  2. To publish the detection information into the IoT platform

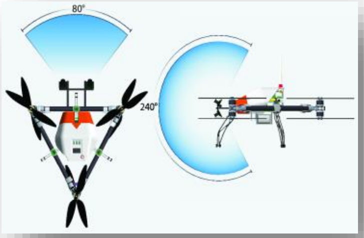
RSU Camera detection Information	Effect on the Automated Valet Parking
Extension of Routing and PMS services capability	- Dynamic routing to parking location; - Optimizing complete parking operation - Benefit of the IoT platform as standardised middleware to publish and subscribe the data







MAV (Drone) Application
Mobile Detection



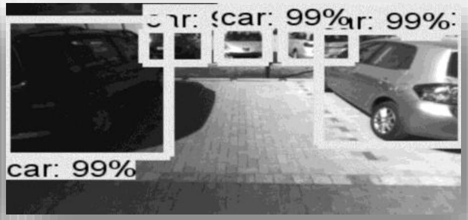
Free parking spot detection

- MAV and ground-station PC act as IoT device
- Custom coaxial tricopter designed by DLR
- Equipped with two pairs of stereo cameras

Workflow:

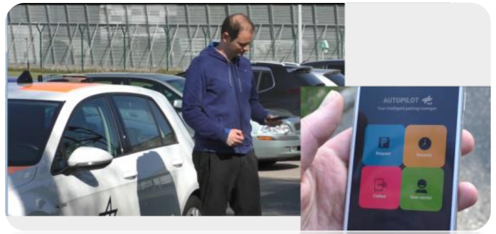
1. Receives IoT command from PMS to check the status of particular parking spots
2. Flying autonomously to the parking spots and taking an image
3. Sending the image to a base station
4. Publishing results to the IoT platform
5. Flying back to the starting position

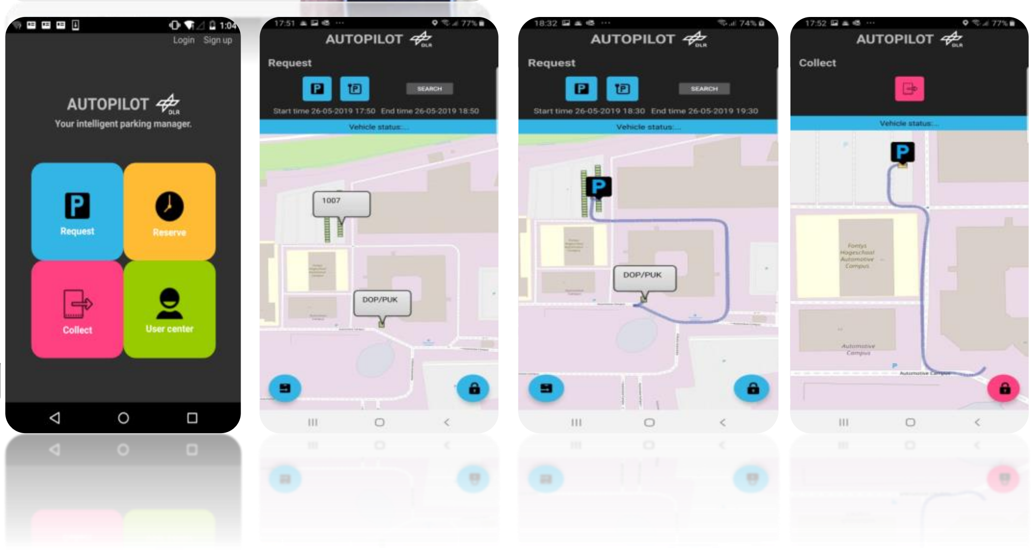
MAV detection Information	Effect on the Automated Valet Parking
Extension of PMS services capability	- Optimizing complete parking operation - Benefit of the IoT platform as standardised middleware to publish and subscribe the data



AVP Smart phone Application

AVP mobile App

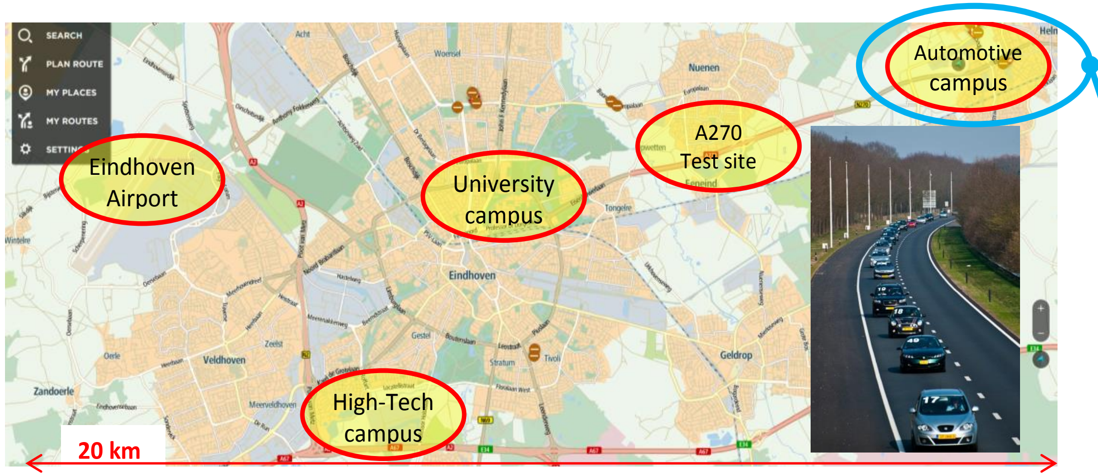


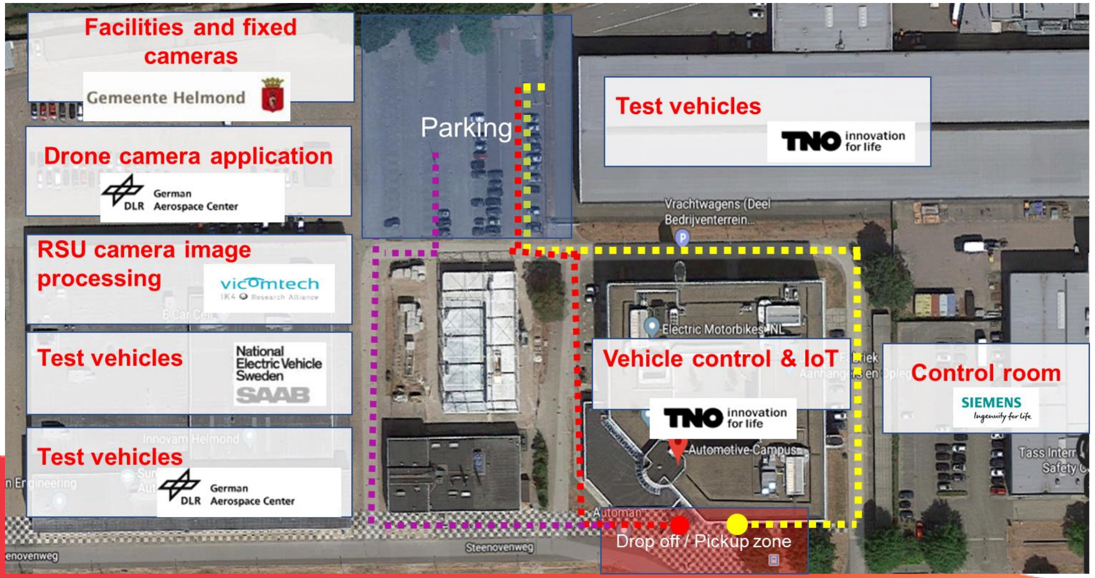


- Developed with Android API
- Consists of SOAP web services and IoT interface
- Supports vehicle “**Parking**” and “**Collection**” scenarios
- Provides information about the valet parking process to the user.

Brainport Pilot Site (The Netherlands)

Test location: Automotive Campus, Helmond

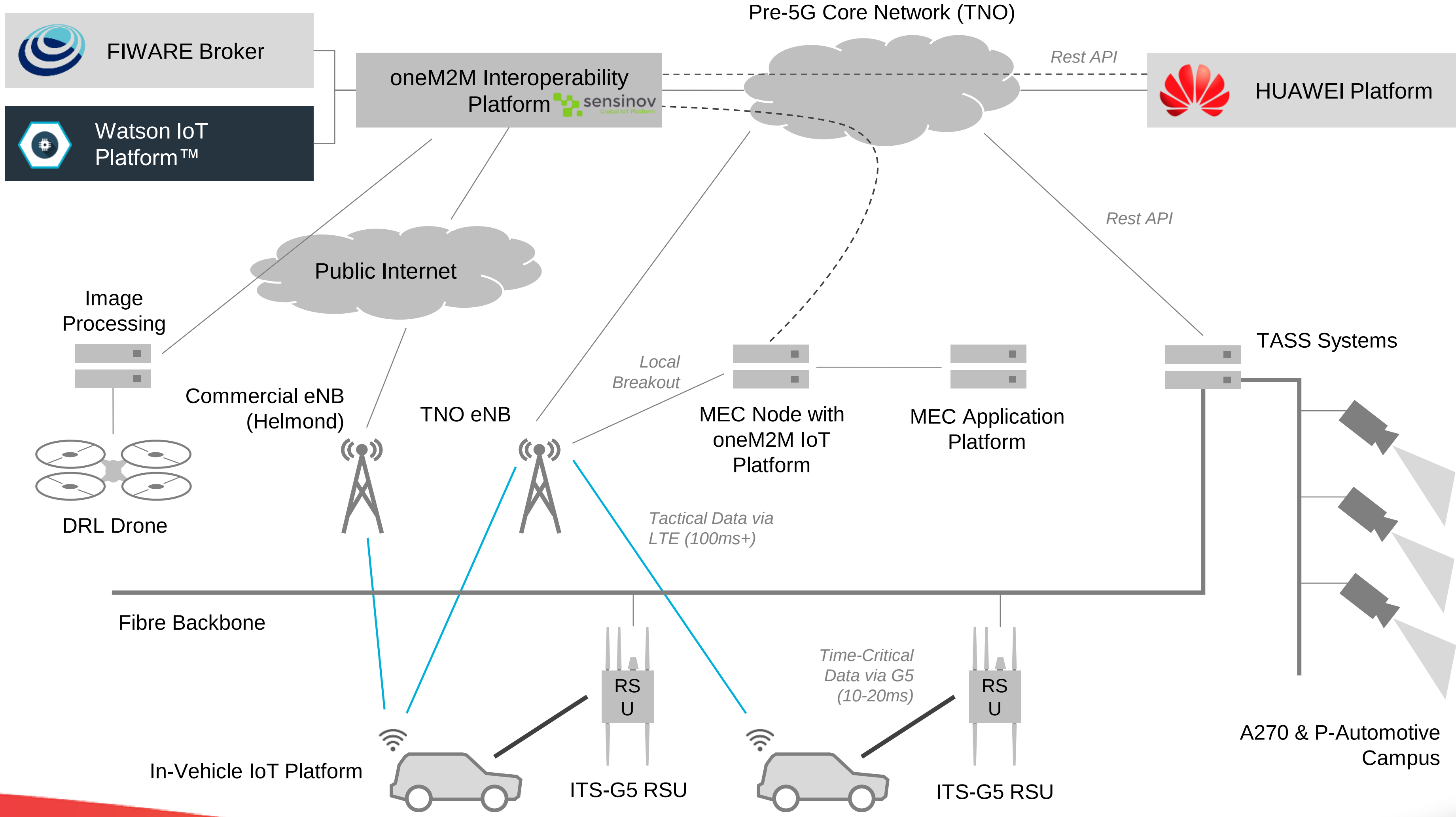




AVP test site and equipment in the pilot site Brainport

Brainport Pilot Site (The Netherlands)

Use Cases	Brainport
Automated valet parking	X
Highway Pilot	X
Platooning	X
Urban Driving	X
Car/Ride Sharing	X
Car Rebalancing	X



Data management

- During the technical tests log files of the system components have been collected in CVS file format and uploaded into the CTS server.
- These data have been used for the technical evaluation of the AVP use case in the three pilot sites

Data Management / log files
Vehicle state log data
Vehicle
Positioning system
Vehicle dynamics
Driver vehicle Interaction
Environmental sensors relatives
Vehicle IoT communication log data
Vehicle IoT event message (PositionEstimate)
Vehicle IoT event message (VehicleAVPStatus)
Vehicle IoT Command message
RSU IoT communication log data
RSU Camera IoT event message (Parking spot occupancy)
RSU Camera IoT event message (Obstacle occupancy)
MAV IoT communication log data
MAV IoT event message (Parking spot occupancy)
MAV IoT command message
Platform IoT communication log data
IBM IoT log message
oneM2M IoT log message

3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_action.csv	08.07.2019 08:41	CSV-Datei	2.165 KB
3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_driver_vehicle_interaction.csv	08.07.2019 08:41	CSV-Datei	236 KB
3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_environment_sensors_relative.csv	06.06.2019 16:48	CSV-Datei	1 KB
3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_event.csv	08.07.2019 08:42	CSV-Datei	1 KB
3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_iot-log-communication_json.csv	02.07.2019 14:57	CSV-Datei	577 KB
3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_positioning_system.csv	08.07.2019 08:42	CSV-Datei	2.425 KB
3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_sensors.csv	06.06.2019 16:48	CSV-Datei	1 KB
3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_uper.csv	08.07.2019 08:43	CSV-Datei	37 KB
3101_2019-06-06_12-44-00_TNO-Vehicle-Dropoff-2_vehicle_control.csv	06.06.2019 16:48	CSV-Datei	1 KB
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3185_2019-06-06_12-44-00_DLR-PSM-Dropoff-2_iot-log-communication_json.csv	26.06.2019 15:41	CSV-Datei	591 KB
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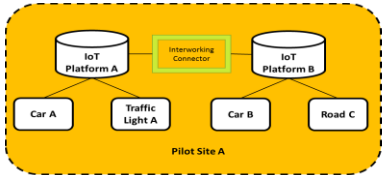
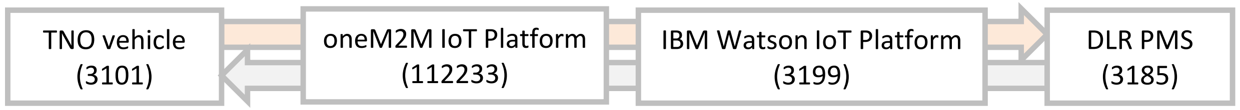
112233_2019-06-06_12-44-00_TNO-oneM2MIoT-Dropoff-2_iot-log-communication_json.csv	02.07.2019 14:56	CSV-Datei	578 KB

CTS: AUTOPILOT Central Test Server

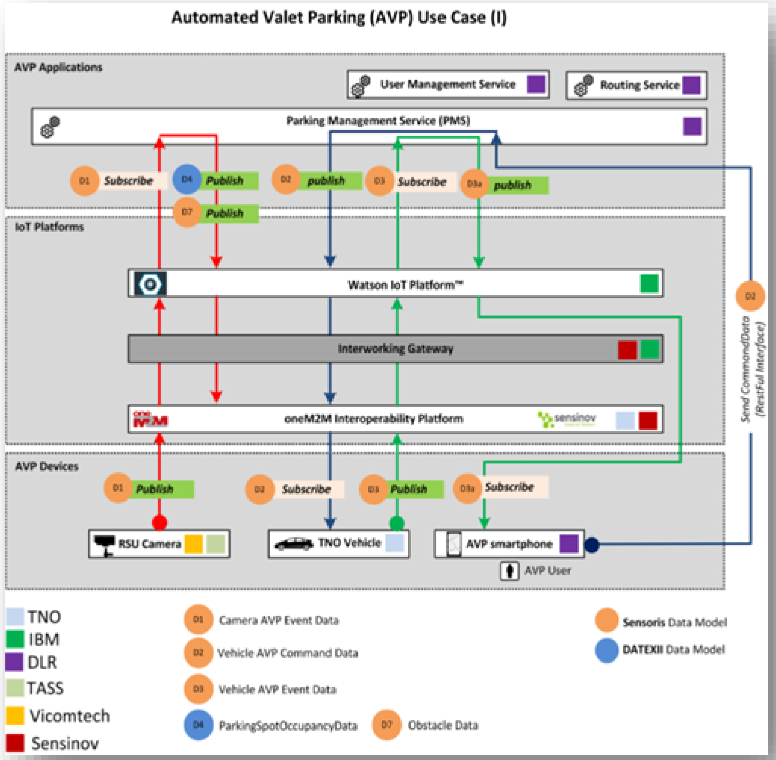
Platforms Interoperability

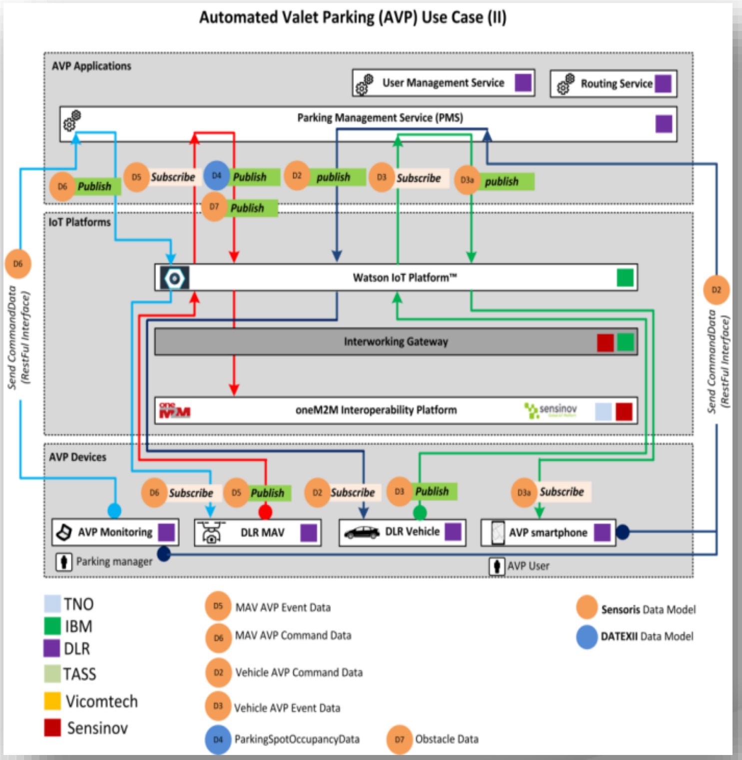
- Two cloud-based IoT platforms are employed in the Brainport AVP pilot realization, namely Watson IoT Platform™ from IBM and OneM2M platform from SENSINOV
- A bidirectional interworking gateway connector allows the interoperability between the two platforms.





Orange: IoT event message Gray: IoT command message





Automated Valet Parking - Technical Evaluation

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

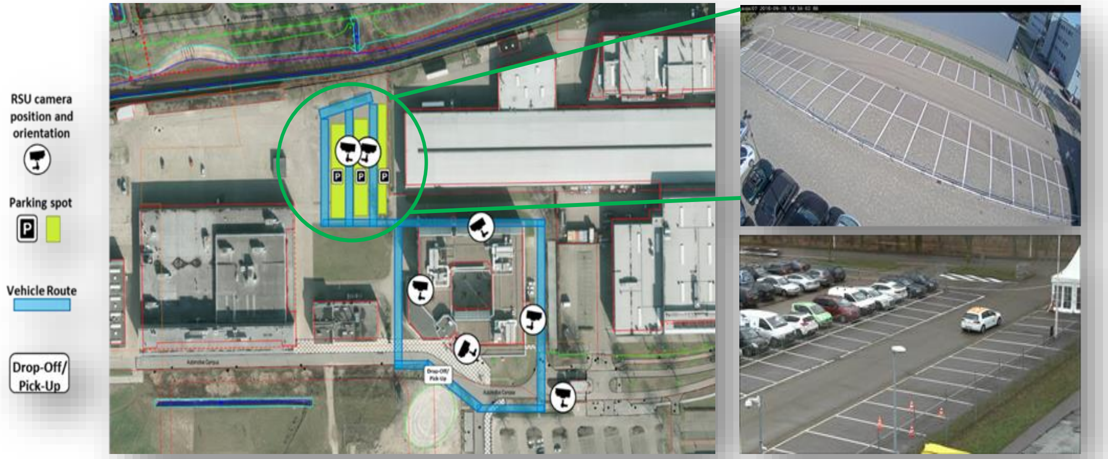
KPI: Key Performance Index

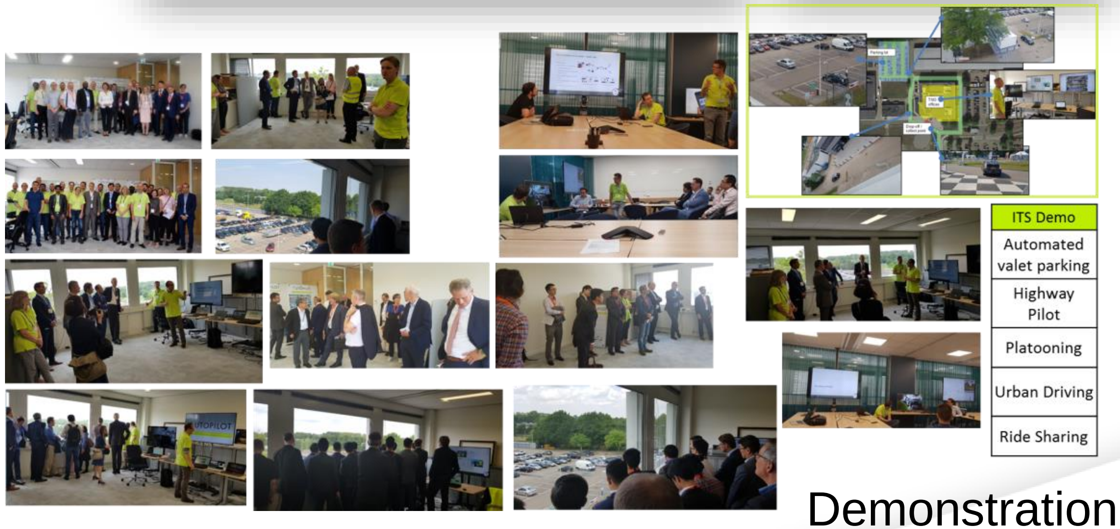
No.	KPI	Measurement	Description
KPI-1	Parking duration	seconds	**Drop-off scenario:** Time from drop-off point until vehicle is parked (parking spot). **Pickup scenario:** Time from parking spot until the vehicle reached the pickup point.
KPI-2	Detection performance of free parking spots (Parking spot 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

AVP Demonstration (Automotive Campus, Helmond)

AVP Use Case has been tested at different pilots and successful demonstrated at the 13th ITS European Congress in Helmond (June 2019)





Demonstration

Thanks for you attention!

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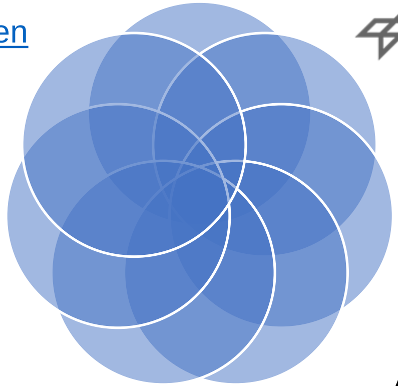
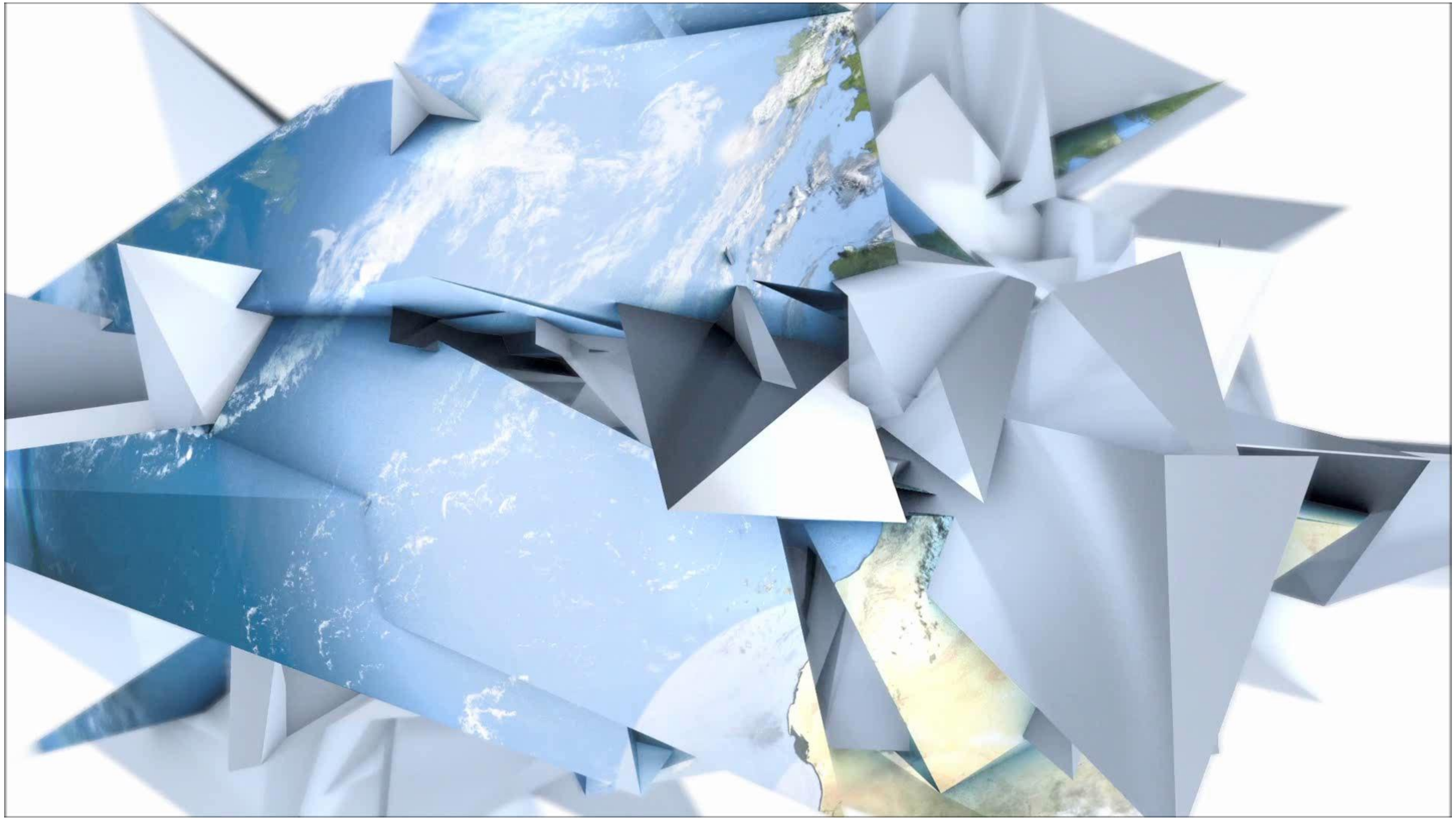


http://autopilot-project.eu/

AUTOnomous driving **P**rogessed by **I**nternet **O**f **T**hings

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

Video



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