Autonomous Driving progressed by oneM2M

the experience of the AUTOPILOT Project

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Abstract— **The European Commission Horizon 2020 AUTOPILOT (AUTOmated driving Progressed by Internet Of Things) is aiming to exploit the IoT ecosystem to integrate connected cars and transform them in automated moving "objects". One of the key challenges encountered in the project is to ensure interoperability of the different components and IoT platforms serving e.g. in-vehicle and road-side devices and sensors. The adopted solution is the use of Federated IoT platforms, with the oneM2M Interoperability Platform used to ensure that all components are able to communicate to each other. This paper provides a high-level description of the project and its goals and then concentrates on the importance to ensure interoperability support for IoT platforms using the standard IoT platform provided by oneM2M.**

Keywords—oneM2M; interoperability; data models; IoT; autonomous driving

I. THE AUTOPILOT PROJECT

AUTOPILOT (AUTOmated driving Progressed by Internet Of Things) is a European funded project aiming to increase safety, provide more comfort and create many new business opportunities for mobility services. The market size of autonomous driving is expected to grow gradually, reaching 50% of the market in 2035. However, regulators are already discussing proposals to increase road safety by mandating the support of ITS technologies [1].

The overall objective of AUTOPILOT is to bring together relevant knowledge and technology from the automotive and the IoT value chains in order to develop IoT-architectures and platforms which will bring Automated Driving (AD) towards a new dimension.

Automated vehicles largely rely on on-board sensors (e.g., LiDAR, radar, cameras) to detect the environment and make reliable decisions. However, the possibility of interconnecting surrounding sensors (e.g., cameras, traffic light radars, road sensors) exchanging reliably redundant data may lead to new ways to design automated vehicle systems, potentially reducing costs and adding detection robustness.

Indeed, many types of connected objects may act as additional sources of data, which will very likely contribute to improving the efficiency of automated driving functions, enabling new automated driving scenarios, as well as increasing the automated driving function safety, while providing driving data redundancy and reducing implementation costs. These benefits will enable pushing the SAE (Society of Automotive Engineers) level of driving automation to full automation, keeping the driver out of the loop [2]. Furthermore, by making autonomous cars a full entity in the IoT, the AUTOPILOT project enables developers to create IoT and autonomous driving services as easily as accessing any entity in the IoT.
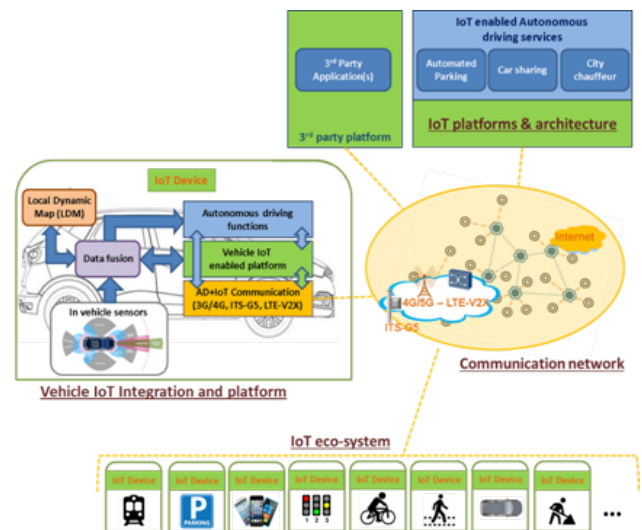

Fig. 1. The AUTOPILOT overall concept.

The Figure 1 depicts the AUTOPILOT overall concept, including the different ingredients necessary to apply IoT to autonomous driving:

- The overall IoT platforms and architecture, allowing the use of the IoT capabilities for autonomous driving,

- The Vehicle IoT integration and platform to make the vehicle an IoT device, using and contributing to the IoT,

- The Automated Driving relevant sources of information (e.g., pedestrians, traffic lights) becoming IoT devices

and extending the IoT eco-systems to allow enhanced perception of the driving environment on the vehicle,

- The communication network, using appropriate and advanced connectivity technology for the vehicle, as well as for the other IoT devices.

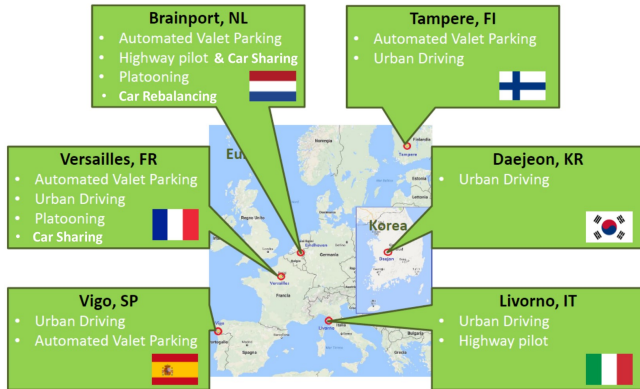These concepts are developed and demonstrated in specific trials called "Pilot sites" within the project.

Fig. 2. Pilot sites and use cases to be demnstrated in each site.

The Project is exploiting six Pilot sites, each one focusing on a number of use cases (see Figure 2):

- Vigo (Spain): Urban Driving and Automated Valet Parking;

- Versailles (France): Urban Driving, Automated Valet Parking and Platooning, Car Sharing;

- Brainport (The Netherlands): Automated Valet Parking, Highway Pilot and Platooning, Car Rebalancing, Car Sharing;

- Tampere (Finland): Urban Driving and Automated Valet Parking;

- Livorno (Italy): Urban Driving and Highway Pilot;

- Daejeon (Korea): Urban Driving.

As common framework for all the use cases, the IoT design follows the AIOTI architectures [3] and encompasses the compliance to the oneM2M standards [4].

A. Standardization - The role of oneM2M in AUTOPILOT – enabling automated driving

In the AUTOPILOT concept objects and people surrounding the vehicle provide data to the IoT platform, in order to create their "digital twin" in the cloud. The IoT platform is then used to support the applications (e.g. Platooning) to be verified in the Pilot sites and enable services to support autonomous driving.

Therefore, it is of utmost importance to ensure interoperability between the different components. OneM2M is he global standards initiative for Machine to Machine Communications and the Internet of Things. The purpose and goal of oneM2M is to develop technical specifications which

address the need for a common M2M Service Layer that can be readily embedded within various hardware and software, and relied upon to connect the myriad of devices in the field with M2M application servers worldwide. In particular, the oneM2M TR-0026 "Vehicular Domain Enablement" [5] contains use cases and requirements for the oneM2M platform. The scope of the document is to examine how the current oneM2M System can be used in the Vehicular Domain and includes a study of advanced features which the future oneM2M release(s) could support for this vertical domain. Note that [5] provides requirements, and that actual status of their implementation in oneM2M platforms is subject to choices and priorities defines by Architecture and Protocols groups of oneM2M.

Besides work on 'how' platform will support autonomous driving, work was needed on 'what' i.e. data models supported by the platform.

Therefore, in AUTOPILOT the standardization plan is based on the following actions addressing oneM2M:

- Introduce data models on automotive domain coming from AUTOPILOT

- Create IoT data models based on use-cases defined in AUTOPILOT

- Create 'need for solution': present AUTOPILOT use cases

- Create 'elements of solution': present data models for the use cases

A set of contributions based on results obtained in AUTOPILOT were agreed and introduced in TR-0026:

- Automated Valet Parking – Automation of the valet parking concept

- Platooning - Platooning is function where vehicle is automatically following another vehicle at a relatively close distance.

- Car Rebalancing – The driverless car rebalancing service is targeted to offer rebalancing of several AD vehicles distributed over several pickup points within a car sharing concept. The AD vehicles will be able to drive automatically (speed limit of 10 km/h) between dedicated pick up points on specific areas, using pre-defined and 3D-mapped tracks and IoT data to improve its world model.

- Highway Pilot - The Highway Pilot function automates highway driving, meaning that steering and speed adjustments are executed by the automated driving system exploiting the information coming from the "smart road". Here IoT sensors and ITS Stations placed in the infrastructure managed by the Traffic Control centers have an effective role in assisting the maneuver in case of road hazards.

- Car Sharing - Car sharing can be interpreted as a service that drive the closest available car to the interested customer.

- Urban Driving - Urban Driving, assisted by IoT has the main objective to support CAD (Connected and Automated Driving) functions through the extension of the Electronic Horizon of an automated vehicle, in order to enhance the Vulnerable Road User sensing.

Moreover, one of the objectives of the project is to demonstrate the interoperability of the different solutions developed within each Pilot site. This will be demonstrated by a test fest planned for Year 3 of the Project (2019).

II. IoT Interoperability

A. The AUTOPILOT Architecture

The AUTOPILOT target IoT architecture aims to provide a global IoT service coverage through features such as openness, flexibility, interoperability between IoT platforms, leveraging of standards for communication and interfacing and federation of in-vehicle, road-side unit and Pilot site IoT platforms.

Given that AUTOPILOT has several large-scale Pilot sites, the architectural components of the open IoT platform (e.g., infrastructure, IoT devices, services) are inherently physically distributed. AD functions themselves have varying requirements in terms of speed of access (latency), availability and range (covered area). While some localized mission critical functions, such as warning other vehicles in the immediate proximity that a pedestrian is jaywalking, need to be accessible within very low latency. Other functions, such as notification about a parking spot being made available, need to cover wider areas but are less demanding in terms of latency.

Therefore, looking at their requirements - not all data is equal. Some of it is time critical, some safety critical, while for some other type of data that is not the case.

This fact can be also seen in the approach that AUTOPILOT has adopted regarding where data is processed. As we know, IoT platforms can also be distributed (looking at for example at oneM2M functional architecture as guideline), and thus data can be collected and processed in different locations in the network and participating devices. Figure 3 illustrates the distributed data collection and processing in the AUTOPILOT IoT Architecture. There are several layers of IoT platforms deployed on a variety of physical infrastructures starting from the in-vehicle IoT layer to the top-level internet cloud-based IoT platform.

As Figure 3 shows, data may flow from any level to any level as required by the use cases. At a given level, data may be processed to generate new information that may be published to an IoT platform at another layer. For example, image data submitted by a dash camera to the in-vehicle IoT platform may be processed inside the vehicle and, upon detection of an object or hazard on the road, a message may be generated and submitted to the road-side and/or central (cloud) IoT platforms.

B. Federated IoT platforms in AUTOPILOT

Many IoT platforms (often proprietary) have been developed worldwide, lacking a de facto standard solution. This situation is also found in AUTOPILOT, where several partners bring their IoT solutions with the common goal and

vision that interoperability is the key for wider acceptance and adoption of IoT. The oneM2M platform is the tool chosen by the project to ensure interoperability of the different components.
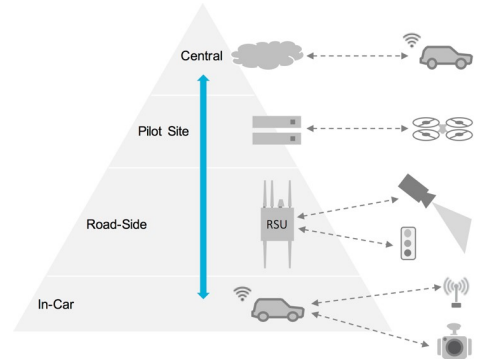

Fig. 3. Distributed data collection and processing in the AUTOPILOT IoT Architecture.

Figure 4 shows the AUTOPILOT target IoT architecture. As shown in this diagram, 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.
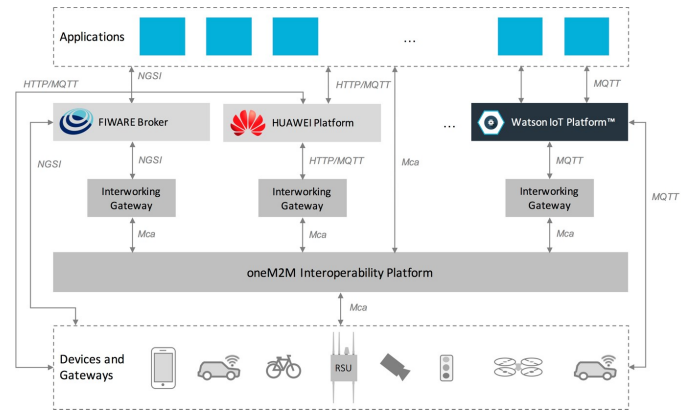

Fig. 4. AUTOPILOT Federated IoT Architecture.

We distinguish the following two types of cloud IoT platforms:

1. Proprietary IoT Platforms: these are used by some applications and use cases to exchange specific data with specific devices or vehicles. For example, the Brainport car sharing service and automated valet parking service use Watson IoT Platform™ to collect data from their vehicles. Several proprietary IoT platforms are used in AUTOPILOT for various purposes, use cases and Pilot sites.

2. oneM2M Interoperability Platform: this is the IoT platform for exchanging IoT messages relevant to all autonomous driving (AD) vehicles.

The proprietary IoT platforms are networked through the oneM2M interoperability platform and are connected to this through oneM2M interworking gateways. The interworking gateway of a given proprietary IoT platform may be configured

to share selected data types with the interoperability platform. Such data will then become accessible to all the connected IoT platforms through the oneM2M interoperability platform. This is particularly useful for sharing data relevant to all the AD vehicles and applications, such as detected hazards, vulnerable road users, objects, and so on.

Interoperability in AUTOPILOT is achieved based on the following three principles:

- oneM2M Interoperability Platform and Interworking Gateways: proprietary IoT platforms are interconnected through interworking gateways and the oneM2M interoperability platform.

- Standardized IoT Data Models: IoT data requiring to be exchanged across the IoT platforms are standardized.

- Standardized Ontologies: to achieve semantic interoperability, IoT data fields values are semantically standardized in ontologies.

Each of the above interoperability principles is discussed in the following sections.

C. oneM2M Interoperability Platform and Interworking Gateways

An interworking gateway is a oneM2M wrapper towards a proprietary IoT platform, allowing it to expose a oneM2M Mca[1] interface and to be connected to the oneM2M interoperability platform. The oneM2M defined the Mca reference point used to interface an oneM2M AE (Application Entity) and oneM2M CSE (Common Services Entity).

The oneM2M platform serves as the bridge for interoperability, allowing data to flow from one IoT platform to another in both directions. Using this architecture, an IoT platform may push data to other IoT platforms and receive from them.

Mapping between the internal data representation of an IoT platform and the oneM2M message contents are specified in the interworking gateways. These also act as filters allowing only selected data to be exchanged.

In this architecture, data providers or consumers, such as applications, may use any of the available IoT platforms according to their requirements. For instance, a data provider may publish data to the Watson IoT platform and this data can be shared with the FIWARE IoT platform [6] through the oneM2M platform, so that an application developer who uses the FIWARE IoT platform can access it through the FIWARE IoT platform.

This approach offers flexibility to the Pilot sites and application developers. On the other hand, for this to work, data providers and consumers need to exchange data with the oneM2M platform using standard data models and vocabularies as explained in the following sections.

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[1] See
https://www.etsi.org/deliver/etsi_ts/118100_118199/118101/02.10.00_60/ts_118101v021000p.pdf

D. Standardized Data Models

oneM2M provides a standard protocol for exchanging IoT messages, but it does not specify the content of the messages as this is domain specific. To achieve interoperability in AUTOPILOT, we have developed standardized contents of the oneM2M messages that are exchanged between the IoT platforms, devices, applications and vehicles, through the oneM2M interoperability platform. A Data Modelling Activity Group (DMAG) was created in AUTOPILOT for this purpose.

The scope of the data model standardization activity in AUTOPILOT covers the IoT messages and data fields required to implement the project's use cases uniformly across the Pilot sites. This will allow AD vehicles to access the data with known data models regardless of their locations (Pilot sites) and to be able to process the data and work with it. For instance, a message notifying AD vehicles about a hazard on the road, or instructing them to avoid a given road lane, should be the same in all Pilot sites, allowing vehicles to consume these messages and react to them correctly as they are moving from one place (e.g., Pilot site) to another.

E. Standardized Ontologies

Data standardization deals with the structure of the IoT messages exchanged and their field names, types, values and units of measure. This usually works only to a certain extent, as some fields remain challenging to standardize. This is specifically the case when dealing with enumerative fields whose possible values are too numerous to be specified exhaustively in advance, or are language-dependent or use-case-dependent (e.g., vehicle types, detected object types, hazard types, proprietary vehicle parameters).

AUTOPILOT adopted ontologies that define the common values of the data fields and provide semantic mappings between them. This constitutes a compromise between openness and flexibility and field value standardization.

III. THE LIVORNO PILOT SITE

As an example of the way of practical implementation of the above concepts, the following Section describes the Livorno Pilot site.

A. oneM2M instantiation in the Livorno Pilot Site

The Livorno Large-Scale Pilot Site is located from Florence to Livorno, including a highway and an urban track inside the Livorno Sea Port. It has been adopted as "smart roads" according to the new ministerial decree that allows in Italy the experimentation of AD vehicles in real traffic conditions [7].

IoT devices are deployed in the car and along the roads in both the Highway and the Urban Area. In the former scenario road side sensors and ITS-Stations managed by the Traffic Control Centre (TCC) are used to warn AD cars about hazardous situations, like heavy floods or road works. In the urban scenario "smart traffic light" and IoT sensors on the bicycles are used to enforce the safety of vulnerable road users, when AD cars are approaching.

Seven JEEP Renegade prototype vehicles are used: two connected cars with AD functions and five connected cars without AD functions. A connected bicycle prototype is also used in the urban tests. The MONI.C.A.™ Port Monitoring Centre in the urban scenario and the real highway Traffic Control Centre with DATEX II [8] node are integrated into the ICT infrastructure of the Pilot Site.

The driving modes, (notably highway and urban), the services for the car (so called, "Driver Assistant Supported by Internet of Things") and the monitoring and control applications are supported by the ICON oneM2M platform managed by TIM S.p.A., as shown in Figure 5.
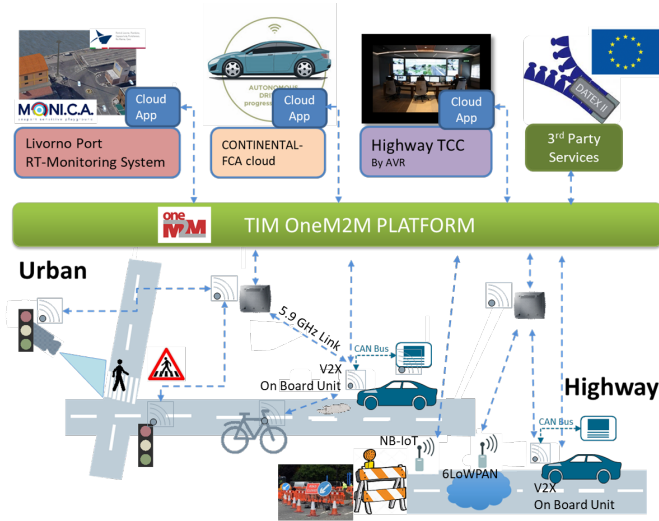

Fig. 5. Livorno Pilot Site: use cases and services enabled by the oneM2M platform.

The ICON OneM2M platform is provided as Platform as a Service (PaaS), with a specific tenant dedicated to the Livorno Pilot site. The platform is oneM2M compliant, so it can interface all devices that natively adopt the oneM2M protocols.

In Livorno Pilot site most of the devices of the IoT ecosystem are oneM2M compliant, including NarrowBand-IoT (NB-IoT) [9] sensors, Road Side Units (RSUs) and Onboard Units. Nevertheless, some other source of information requires the development of adapters. It is the case of the DATEX II node providing real time and verified traffic information of the highway. The adapter has been implemented as a SOAP-Web service that starting from the content of DATEX II messages in XML format, converts it to JSON format, but without SOAP envelope that is useless in the oneM2M context.

Starting from the use cases and based on ETSI C-ITS [10], SENSORIS [11] and DATEX II [8] legacy data models, a new data model supporting IoT services for AD cars has been created. The data model has five packages: RSU, NB-IoT, DATEX II, TCC, Vehicle; each one corresponds to a content instance in the device tree of the oneM2M platform.

Many weeks of experimentation have been executed in real traffic situation; on top, stakeholder workshops and public demo events have been performed. The purpose of those events was to feed the evaluation tasks that investigate how IoT could offer improvements to automated driving according to different aspects: technical, business impact, quality of life, user acceptance.

IV. CONCLUSIONS

The AUTOPILOT project shows that OneM2M compliant platforms and devices are valuable bricks of the digital infrastructure for accommodating the usage of AD cars in EU roads. The oneM2M standard offers effective tools to manage the challenge of data interoperability in the IoT ecosystem. Within the AUTOPILOT project, a oneM2M interoperability platform has been developed to allow the different proprietary platforms provided by the partners to interwork successfully. The interoperability of different use cases and services is being demonstrated as the outcome of the trials in six full scale pilot sites.

Further work is needed to achieve a seamless federation with the IoT infrastructure emerging from related pilot and project areas (created by the European H2020 Large-Scale Pilots Programme: IoT FA, LSPs and IoT-02-2016 CSA). This will be achieved by contributing to the standardization work groups, who are in charge of mapping the architecture, interoperability and standards approaches at technical and semantic levels [12, 13].

ACKNOWLEDGMENT

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