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"Smart Roads" for AD cars: the AUTOPILOT Project in Livorno

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Abstract

AUTOPILOT goal is to show how the AD cars can participate in the IoT ecosystem getting better application and services. It is declined into six national pilot sites, where specific driving scenarios and services are demonstrated. The Italian Large-Scale Pilot Site is located from Florence to Livorno, including a highway and an urban track inside 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. The driving modes and linked services are demonstrated by several weeks of tests on real road environments. This paper describes the specific features of Livorno Pilot Site: use cases, devices, platforms, adaptations, applications, and results of the ongoing experimentation. The latter includes an evaluation of the business cases, as well as the opportunities and challenges of the related market uptake.

Keywords:

Internet of Things, Autonomous Driving Cars, oneM2M

Introduction

The AUTOPILOT H2020 project concerns the use of Internet of Things (IoT) for enabling Automated Driving. The extent and volume of information sources that can be addressed through Internet of Things is seamlessly unlimited, offering improvements of automated driving functions (including improvements in security, efficiency, accuracy, etc…) and enabling new services for all the different kind of users participating to the IoT ecosystem of the automated driving cars.

Various use cases are implemented at the six Pilot Sites of AUTOPILOT in real traffic demonstrations, in order to evaluate the potential and estimate the related impacts of using the Internet of Things for Automated Driving. As common framework for all the Pilot Sites, the IoT design follows the AIOTI architectures [1] and encompasses the compliance to oneM2M standards [2]. New "IoT enabled" sensors enhance driving environmental perception, IoT platforms are integrated in the vehicles and IoT

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Platforms on the Cloud are used to “store and share” data consumed by new mobility services with fully automated vehicles. Among all applications developed and demonstrated in the project Pilot Sites, in Livorno the focus is on IoT enabled services, such as Road Hazard sensing in the Highway driving and Vulnerable Road Users sensing in the Urban driving.

Livorno Pilot Site features

The Italian Large-Scale Pilot Site is located from Florence to Livorno, including a highway and an urban track inside the Livorno Sea Port (see Figure 1). It has been adopted as “smart roads” according to the new ministerial decree [3] that allows in Italy the experimentation of AD vehicles in real traffic conditions. IoT devices are deployed in the cars 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 are used to warn AD cars about hazardous situations, like heavy floods or road works. In the urban scenario “IoT 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 only connected. A connected bicycle prototype is also used in the urban tests. The MONI.C.A.^{TM} Port Monitoring Centre in the urban scenario and the real highway Traffic Control Centre with DATEX-II node are integrated into the ICT infrastructure of the Pilot Site. The driving modes, (notably highway and urban) and the services “Driver Assistant Supported by Internet of Things” are supported by the ICON oneM2M platform managed by TIM S.p.A., the main telecommunication operator in Italy.

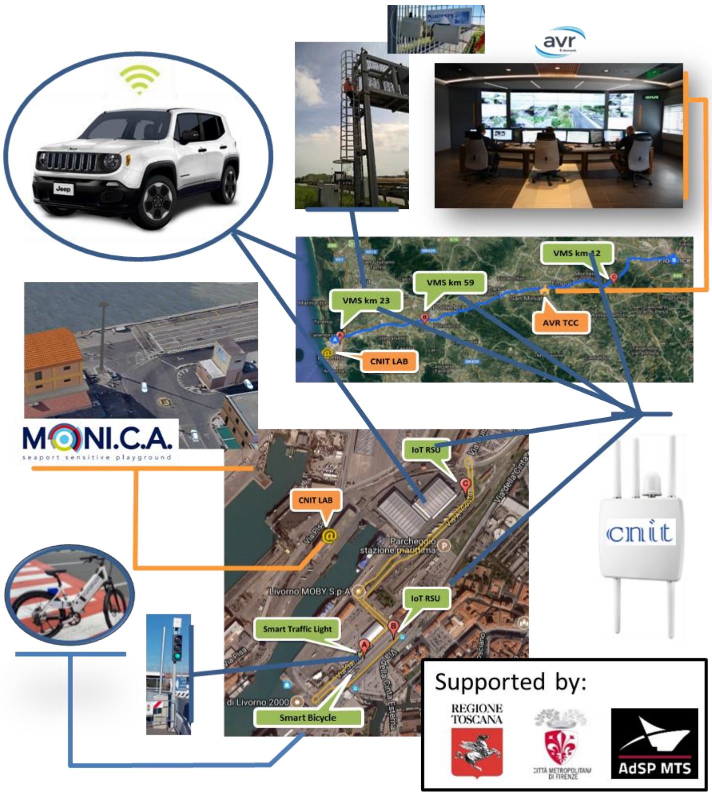

Figure 1 – Overall view of the Livorno Pilot Site.

Use Cases and Services

As mentioned earlier, in the Livorno PS two use cases are demonstrated: Highway Pilot and Urban Driving; on top of that the “Driver Assistant Supported by Internet of Things” service is implemented as follows.

Highway Pilot

The scope of these tests involves cars with IoT-enhanced AD functions, driving in a “smart” highway. The cars are Jeep Renegade prototypes with on-board equipment, the so-called IoT open vehicular platform, enabling IoT-triggered AD functions: speed adaptation, lane change, lane keeping. The “smart” highway is a freeway where a pervasive IoT ICT system is deployed based on a network of roadside sensors or other sources (e.g. DATEX-II node), capable of collecting information and making it available to cloud-based applications. The goal is to show how the combined use of IoT and C-ITS can mitigate the risk of accident, for an AD car, when hazards occur on the road. Here, we deal with two types of hazards: (1) puddles and (2) road-works.

In the first case, the AD car performs IoT assisted speed adaptation due to slippery road: sensors placed along the highway detect a relevant presence of water on road surface. This event triggers a warning that is notified in advance to the vehicle by the IoT. The AD system smoothly brakes and the vehicle reaches the point of interest moving at an appropriate speed.

In the second case, the AD car performs IoT assisted speed adaptation and lane change approaching roadworks: a roadworks site is set up by the traffic/road operator with all the accompanying signage including speed limits and closed lanes. The AD vehicle has to reduce its speed approaching the roadworks area, performing a lane change, travelling at the temporary speed limitation and increasing again the speed at the end of the roadwork area.

Beside the AD cars, also the connected cars and the Traffic Control Centre have an important role: for safety reasons, connected cars drive in a convoy, following the AD car; on the other hand, the TCC validates the information from the roadside sensors and triggers the roadworks warning message.

Urban Driving

This use case demonstrates how IoT may impact the safety of VRUs in an urban-like scenario (instantiated at a harbour settlement) with AD cars, connected cars, pedestrians at a traffic light crossing, connected bicycles, and a sea port monitoring centre.

IoT can provide redundant information that can be fused with other sensors data in order to produce a robust and reliable description of the surrounding environment. In some cases, IoT information is not detectable from common sensing devices, e.g. the remaining time before the traffic light phase changes and in some other cases IoT can provide information in advance with respect to other devices, for preventively acting on the vehicle dynamics, avoiding or mitigating crashes and increasing safety. For example, when a bicyclist falls down in a “smart” urban environment, the hazard warning is broadcasted to the vehicles by IoT based services. AD cars, approaching the accident area can safely slow down and stop, knowing in advance the exact location of the dangerous situation.

Finally, an IoT Smart traffic light can detect when a pedestrian is crossing the road and fuse this information with the current phase of the traffic light. If the pedestrian is crossing with the red signal, a notification is sent to the AD cars that can adjust their speed accordingly. The camera can even detect which is the lane occupied by the pedestrian and report this information to the cars using standard messages (e.g. DENM).

The information sent to the cloud is used also by the port monitoring application (MONI.C.A.^{TM}) that displays the scene from a virtual 3D camera and can change the advisory speed in the relevant area to avoid possible implications.

The overall relevant test scenarios for the Livorno PS are summarised in Figure 2.

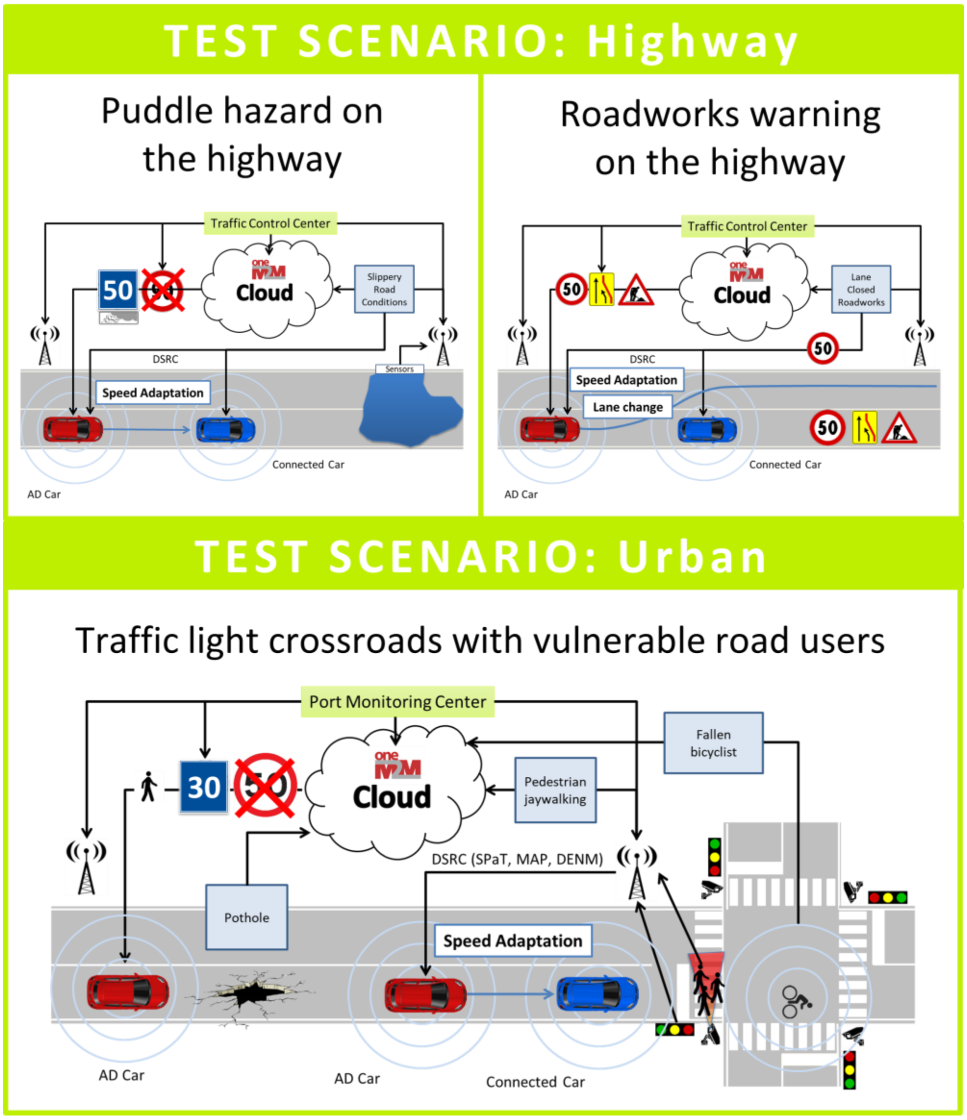

Figure 2 – Use cases demonstrated at Livorno Pilot Site.

IoT – ITS ecosystem

The IoT ITS ecosystem in Livorno PS is a combination of devices, networks, platforms and applications integrated in a standard architecture, as shown in Figure 3. Many devices have been ad hoc developed and integrated in the use cases, considering latency, availability, communication range.

The device collection includes: puddle IoT sensors (based on 6LowPAN and NB-IoT technologies), pothole detector, smart trailer (announcing roadway works), road side units, on board units (cars and bicycle), smart traffic light, smart camera; some of them are shown in Figure 4.

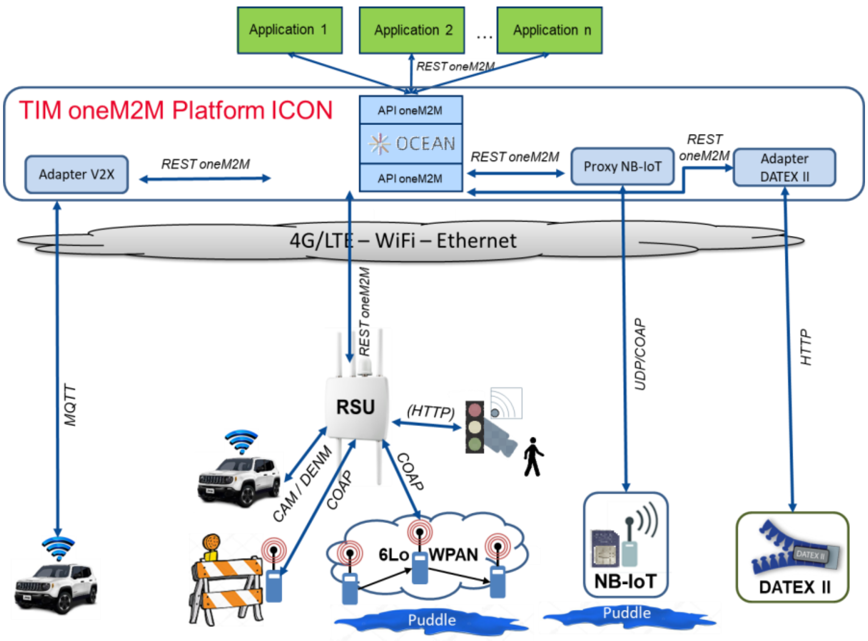

Figure 3 – IoT devices integrated into Livorno Pilot Site.

Different communication networks are used: 4G cellular network, Port Wireless Backbone, Highway Backbone (Tuscan Institutional Cabled Network), ETSI ITS-G5, NB-IoT, 6LoWPAN. All the devices publish or consume data to/from the ICON OneM2M platform. Furthermore, also in the vehicle there is an IoT platform, where the information from different sources can be fused producing a “virtual sensor” as in the case of the pothole sensor.

Figure 4 – IoT - ITS components in Livorno Pilot Site.

Starting from the use cases and based on ETSI C-ITS, Sensoris [5] and DATEX-II 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 device tree of the oneM2M platform.

Security is critical to IoT adoption because the AD manoeuvres must be actuated only if the application can "trust" the data exchanging between sensors, actuators, rules engines, and other connected components of the testbed; furthermore, when IoT is used together with V2X communication, also ITS security features should be integrated. In this regard in Livorno PS, beside the assessment of security feature via specific penetration testing, a Distributed Ledger vehicular PKI is set up, in order to perform extensive tests on emerging blockchain based security infrastructure [4].

Evaluation of User Applications

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.

Although the evaluation activity is still ongoing, some preliminary results can be presented. Regarding the technical aspect, the analysis based on the FESTA methodology [6] assesses that IoT data are effective in accelerating and enhancing AD manoeuvres in road hazard situations and the protection of VRUs in urban driving.

Regarding the business impact evaluation, the relevant AUTOPILOT methodology [7] has been applied to firstly identify the business cases for the aforementioned Livorno Pilot Site Use Cases and the involved key related stakeholders and actors.

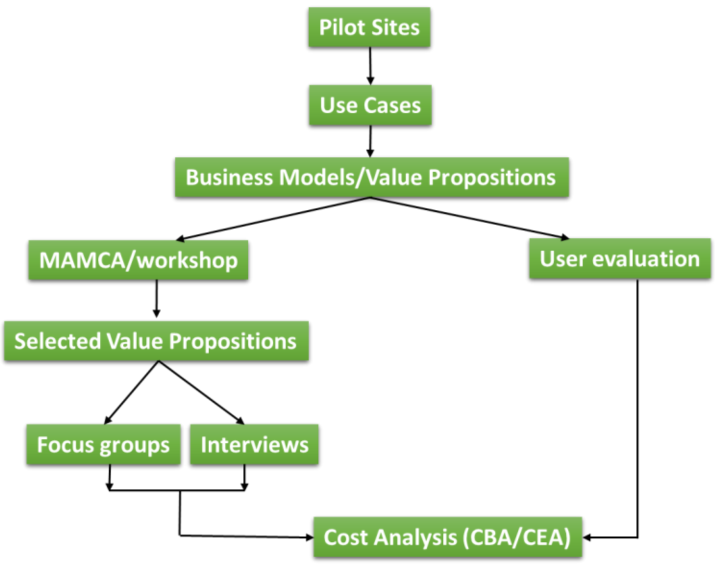

Figure 5 – AUTOPILOT Business Impact methodology [7]

After the drafting of the Business and Value proposition canvases, a dedicated Livorno Pilot Site Workshop attended by AUTOPILOT partners and local stakeholders was organised at CNIT premises (Cruise Terminal Meeting Hall) in October 2018, targeting to discuss the business opportunities for Livorno and evaluate the identified value propositions against each other for each business criterion (six criteria; see Figure 5) by the stakeholders during the Workshop. More specifically, the identified value propositions related to the Livorno pilot site are:

- Protection of VRUs in an urban-like automated Port area
- Automated speed adaptation and lane assistant on the highway for safety procurement
- Integration of corporate ITS in a Traffic Control Centre
- AVP Premium Ticketing Service

In total, 30 participants represented the AUTOPILOT business clusters (10 stemming from industry, 7 from research, 7 from operator & service providers, 4 from authorities and 2 from user representatives) and evaluated the value propositions per criterion. Their input was then processed using the MAMCA methodology [8].

According to Livorno participants, the most important value proposition was considered to be the proposition “Protection of VRUs in an urban-like automated port area”, followed by “Automated speed adaptation and lane assistant on the highway for safety procurement”, as shown in Figure 6 below. This is a reasonable outcome considering the fact that a highly popular, commercial and touristic port like Livorno attracts numerous visitors per day who are exposed to the use of AVs and need to be protected in such an environment, while at the same time, people employed in the freight and transport industry need support to smoothly accept and embrace AVs.

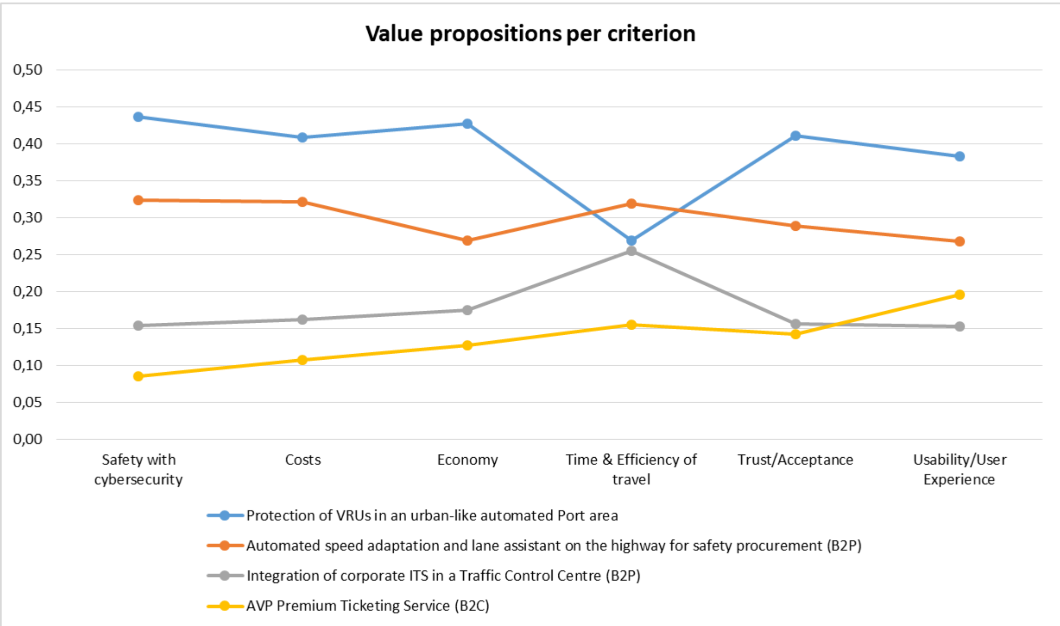

Figure 6 – Value propositions per business criterion for the Livorno Pilot Ste Use Cases [7]

The results of this evaluation will be used to focus the cost-benefit analysis for the top-ranked value propositions at the next phase of the evaluation that will be concluded in October 2019. The CBA will be based on data stemming from user evaluation questionnaires, stakeholder focus groups, key actors interviews and cost-related data for the introduced technology and services that support the IoT ecosystem, as previously presented in Figure 5.

Conclusion

Livorno experience shows that the IoT - ITS ecosystem based on AIOTI architecture and oneM2M compliant platforms, sensors, devices and services are valuable bricks of the digital infrastructure for accommodating the usage of AD cars in EU roads. The oneM2M platform has been extended in order to manage the demanding IoT environment for AD cars. A new data model supporting IoT services for AD cars has been proposed: besides IoT sensors, also DATEX-II node and ITS-Stations have been integrated as oneM2M resources. The "Driver Assistant Supported by Internet of Things" service has been demonstrated in both highway and urban scenarios. Also, the Business Impact of the new service has been preliminary evaluated against a significant sample of stakeholders.

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 [9].

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