AIOTI

ALLIANCE FOR INTERNET OF THINGS INNOVATION

Report

AIOTI WG 9 – Smart Mobility

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Executive Summary

In this document, a number of analyses, considerations and recommendations have been explained. The draft report defines the scope and focus of the WG and in particular considers applications of the Internet of Things to the mobility domain (Internet of Vehicles) as next step for future smart transportation and mobility applications with short-termed European wide economic potential and applicability.

An overview is given of existing relevant initiatives in the domain including EU projects, European Technology Platforms, or related initiatives like the C-ITS Deployment Platform or ECSEL. The report defines criteria including contribution to standards, usability and user acceptance, security and data privacy issues, necessity to demonstrate synergies and spill over effects with other areas and providing at least TRL 6/7+.

Based on relevant work by e.g. ETSI, the WG has discussed categories of use cases for Large Scale Pilots (LSPs) in the “Autonomous vehicles in a connected environment” domain. The framework for recommendations concerning the LSPs is given in the Work Programme 2016-2017 of Horizon 2020. Therefore, these recommendations are intended to provide clues for the Commission in the context of the IoT Focus area. However, it is important to note that no LSP for Level 5 automated driving can be realized within the next years. Therefore, any LSP need to focus on Level 3-4 and demonstrate IoT technologies which pave the way for sustainable business models for future Level 5 automation. Technical and non-technical criteria and aspects of LSP include for example European and societal value, user attractiveness, technology maturity and the contribution to the employment of automated driving by utilization of IoT. As potential topics of LSP have been identified Connected Parking (e.g. automated valet parking) and highly automated freight transport in e.g. sea ports. Of course, other applications at the interface of automated driving and Iot like real time safety services (electronic horizon, dynamic map, etc.) are not excluded.

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2 Scope, framework, and rationale of the Working Group

The "Smart mobility" working group considers applications of the Internet of Things (IoT) to the mobility domain with short-termed European wide economic potential and applicability. The IoT holds the potential for major disruptive effects across a wide variety of market sectors, where mobility applications comprise e. g. rapidly emerging self-driving and connected vehicles, multi-modal transport systems and ability to develop “intelligent” transportation infrastructure like roads, sea ports to parking garages. The IoT technology will affect the future automated and autonomous vehicles on land (road, agriculture, storage facilities, construction, etc.), underground, air (airplanes, helicopters, drones, etc.) and water (ships and submersible vehicles).
The concept of Internet of Vehicles (IoV) is the next step for future smart transportation and mobility applications and requires creating new mobile ecosystems based on trust, security and convenience to mobile/contactless services and transportation applications in order to ensure security, mobility and convenience to consumer-centric transactions and services. However, from the plethora of possible applications a priority is given to IoT aspects (“connectivity”) for automated passenger cars and relevant interfaces to other transport modes. Other transport modes and IoT domains in mobility should be considered in a similar manner at a later stage, for example dynamic road infrastructure, freight transport, or cloud-based predictive maintenance services.

The rationale behind this is twofold. On the one hand, Europe has a very strong industrial basis on automotive technologies and systems. The automotive industry is the largest private sponsor of R&D in Europe: Four out of the TOP5 companies investing most in R&D in Europe are automotive companies. On the other hand the automotive value chain and a typical IoT value chain are becoming more and more entangled: Pure hardware and classic steel are no longer sufficient to maintain global leadership of Europe’s car industry - because a car is becoming more and more a “Thing” in the Internet of Things.
Therefore, adaptations for future trends are needed: cleaner, safer, smarter – and connected highly automated driving is the key to that. One crucial aspect of connectivity is security, as the means and ways of preventing, detecting, and responding to unauthorized access, eavesdropping, jamming, and spoofing.

As a consequence, intense but healthy competition arises not only between technologies or companies but as well between legal systems, countries or even multi-national markets. In the USA, four states (California, Nevada, Columbia and Florida)[1] have already adopted the laws governing the usage of autonomous cars on public roads. European initiatives like ERTICO or the C-ITS platform are working on this barrier. Further global trends like urbanization, higher sustainability standards or ageing population increase the demand for innovation and strategic thinking. These challenges are so large that neither one company nor one country can resolve all of them on its own.
For example, the enormous financial resources of Silicon Valley combined with a large single market and unbroken global dominance in data based business models are challenging Europe’s backbone industry – the automotive sector. Fast innovation cycles are common in the IT sector and becoming more and more important in the automotive world. This poses the risk that fast moving IT sector sets quasi-standards which are not optimized in terms of e. g. European perception in data privacy or technical safety.

Numerous studies demonstrated that Connected & Automated Driving offers a great opportunity to tackle some of the grand challenges of our society such as “Vision Zero” of traffic fatalities: The European Commission’s White Paper on Transport[2] announced the ambitious goal to reduce the number of deaths on European roads by a half until 2020 and the automated driving including the communication technologies applied to transportation systems will be key support towards a new set of safety and efficiency services. Among them, cooperative collision avoidance among all means of transport, pedestrian protection, automated driving, traffic jam prediction and mitigation, or next generation navigation systems will be key services towards achieving this goal.

[1] Comparative Analysis of Laws: www.auvsishow.org/auvsi2014/Custom/Handout/Speaker8657_Session789_1.pdf
[2] http://ec.europa.eu/transport/themes/strategies/2011_white_paper_en.htm

Connected & Automated Driving will minimize our carbon footprint and pollutant emissions, and allow democratic integration of people with disabilities in the traffic systems for individual mobility. Large scale pilot projects (LSP) can play a crucial role in this development. And finally, as a recent study[3] puts it: “Autonomous vehicles do not drink and drive.”

Reduced congestion: fewer traffic jams and less waiting time at intersections and lights **⇒ 80% improvement in traffic throughput[4]**
Higher fuel efficiency I: synchronized traffic flow and increase in road capacity **⇒ 13% improvement in highway fuel economy[5]**
Higher fuel efficiency II: Truck platooning **⇒ Platooning yields average fuel savings of 10% with two vehicles[6]**
Gain in productivity I: time in transit becomes more productive **⇒ About 1 hour per day freed up for other uses[7]**
Democratization of mobility: over-65 segment growing 50% faster than overall population **⇒ Allow a variety of age ranges to be mobile**
Improved safety: 90% of all accidents caused by human errors **⇒ Reduction in motor vehicle accident rates**
More efficient usage of existing transport infrastructure (smaller footprint) **⇒ closer driving on motorways (platooning) or closer parking (e.g. automated valet parking)**

Figure 1: Some social benefits of connected & automated driving

Autonomous vehicles will gradually gain traction in the market over the two decades from about 4% of the global light-duty vehicle market in 2025, rising to roughly 41% in 2030 and 75% by 2035—about 95.4 million units annually by then[8]. The opportunity in autonomous vehicles is currently led by the United States and Europe, but China and other Asian countries will grow rapidly to overtake U.S. and Europe in vehicles sales share. A recent report from Lux Research[9] states that by the next decade, automakers will come to market with some advanced autonomous vehicles, and across this new value chain the revenue opportunities will total $87 billion in 2030. Other target markets are mobility providers for parking, traffic, logistics, and public transportation providers including e. g. municipalities or start-ups.

[3] Fagnant, D. & Kockelman, K., Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations (2015) Transportation Research Part A 77, 167–181
[4] Shladover, Steven, Dongyan Su and Ziao-Yun Lu (2012), Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow, 91st Annual Meeting of TRB, Washington
[5] Atiyeh, Clifford (2012), Predicting Traffic Patterns, One Honda at a Time, MSN Auto, June 25
[6] Janssen, Robbert et al. (2015), Truck Platooning – driving the future of transportation, TNO (Report: TNO 2014 R11893)
[7] US Department of Transportation Highway Safety Administration (2011), Report # FHWA-PL-II-022
[8] Navigant research: Self-Driving Vehicles, Advanced Driver Assistance Systems, and Autonomous Driving Features: Global Market Analysis and Forecasts
[9] https://portal.luxresearchinc.com/research/report_excerpt/16874

2.1 IoT on Intelligent Transportation Systems

The evolution of the internet towards the Future Internet, with the Internet of Things (IoT) as one of the main drivers, is defining an extension from the initial industrial internet, where several sensors, actuators and devices (now called things), are connected to the internet through gateways and Supervisory Control And Data Acquisition platforms (SCADAs). This Intranet of Things is being extended to smart things with a higher scalability, pervasiveness, and integration into the core of the future internet.

This Extranet of Things, is starting to be located on the internet, addressable through internet addressing (i.e. IPv6), and consequently accessible through internet protocols such as web services. The on-going and future work is the creation of an extended IoT, which requires from the beginning a design of the solutions and products considering the requirements for the integration of the internet technologies, in order to reach a homogenous integration of the future internet, services, people, and the things reaching the Future Internet of Things, Services and People.

This drive to integrate everything into the internet core is motivated by the market wishing to have all processes remotely accessible, together with an understanding that re-engineering an infrastructure to allow this for each application would be prohibitively costly and time-consuming. Moreover, the current evolution from uniform mass markets, to personalized ones, where the customization and user-specified adaptation is a requirement, makes a uniform infrastructure, the internet, imperative. This allows many components to be re-used, and services to be shared, with correspondingly huge economies of scale and shortened completion times. Clients are always looking for new areas where this infrastructure can be employed. One example is logistics, where there is need to trace small deliveries for customized products from e-business. Other areas are health (where personalized healthcare is allowing the adaptation of the therapy to the context and status of the patient, building automation (where user feedback allows energy-usage optimization from more user involvement, better usage information provision and more ubiquitous control), and smart cities (where citizens want to locate a free parking place for his car) and, generally speaking, Intelligent Transportation Systems, where vehicle and roadside sensors could be remotely accessed and, what is more important, IPv6-addressed.

IoT fills the gap between the needs from the evolution of the market, information, users, and things, through moving all of them to a common framework: the internet. This will be different from the current approach, where applications are based on isolated solutions. Users now require more flexibility and freedom. Offering a common framework allows choice among the available manufacturers, suppliers, service providers, delivery options, and payment services. While this will obviate the need for stand-alone or proprietary solutions, it requires a high level of integration. In fact, it requires a Future Internet of Things, Services and People.

As can be noted, one further step is reached for the integration of IPv6 in the IoT, which is part of the coexistence strategy to manage the heterogeneity of the involved technologies and architectures, in order to meet the interoperability across business, service providers, and users.

2.2 Vision: Overcome the “chicken and egg-problem”

For the IoT smart mobility applications it is important to consider that many automotive stakeholders follow an incremental development course and considered automated driving technology as an add-on to existing driving modes. The new entrants like Google, Tesla, or Apple have a different approach and are using partly disruptive business models to enter the market. In addition, financial resources of Silicon Valley for major investments in these technologies are available. Just the five firms Apple, Microsoft, Google, Cisco Systems and Oracle have cash reserves of nearly € 400 billion together. Apple, with at least €160 billion, holds 10% of total corporate cash outside the financial sector: more in cash reserves than many entire industries.

The WG on Smart Mobility will support the dialogue and interaction among IoT stakeholders to create a dynamic European IoT ecosystem in large scale pilot projects. The members will build on the work of other initiatives and spill over innovation to other domains. The integration of ready-to-use technologies for sustainable business models has a high priority: Overcome the “chicken and egg-problem” to enable IoT business in smart mobility.

Within AIOTI, among the vertical WGs the WG on Smart Cities[10] is in particular relevant to this WG.Furthermore, the Smart Mobility WG foresees synergies and cooperation with all the horizontal WGs like the IoT European research cluster (WG1) or Working Group 4 which is to identify existing or potential market barriers that prevent the take-up of the Internet of Things, with a particular focus on trust, security, liability, privacy and net neutralit. In its policy document, WG4 highlights a number of key issues related to each of these areas. The AIOTI WG3 has provided their views on the IoT standardisation that are covered in 3 documents: "IoT Landscape and IoT LSP Standard Framework Concepts", "IoT High Level Architecture (HLA)", "Semantic interoperability" recommendations for IoT LSPs. The documents delivered describe and summarise the outcomes of the discussions within the AIOTI WG3 and reflect the interaction with the other AIOTI WGs. The work is seen as a reference for the AIOTI WGs in different domains in order to address the standardisation issues and to recommend the use of standard-based solutions for the deployment of IoT solutions in future projects. The documents offer an extensive overview of the IoT standardisation landscape and do not prescribe methods to achieve the implementation of the IoT solutions in different domains. This allows the stakeholders involved future projects to be flexible and innovative in their use of the information, while assuring that they provide standard-based and interoperable IoT implementations.

2.3 Objectives

The first objective of the WG was to define criteria, prioritize use cases and the framework for LSPs in the “Autonomous vehicles in a connected environment” domain. Taking into account existing studies[11] some important criteria include (see chapter 4):

- Overcome the “chicken and egg-problem” to enable IoT business
- Contribute to standards
- Usability and user acceptance in an existing and future smart mobility ecosystem
- Security and data privacy
- Demonstrate synergies and spill-over effects with other areas
- Provide Technology Readiness Levels of 6/7 or higher

As typical use cases the WG discussed for example:

- Connected parking (sensor-based parking management, automated valet parking)
- Real time safety services (electronic horizon, dynamic map, wrong way driver warnings, etc.)
- Highly automated freight transport and interfacing between open traffic and industrial logistics also having a link with ”Industry 4.0” in e.g. sea ports
- Predictive maintenance via open telematics platforms

[10] AIOTI Smart Cities Working Group, Report on Analysis and Recommendations for Smart City Large Scale Pilots (Sep. 2015)
[11] Benchmark study for Large Scale Pilots in the area of the Internet of Things, EU Commission (2015), http://ec.europa.eu/digital-agenda/en/news/benchmark-study-large-scale-pilots-area-internet-things

2.4 Definitions

First of all, for pragmatic reasons the term Connected & Automated Driving in this report includes automatic or driverless vehicles and autonomous driving.
There are plenty of IoT technologies and standards that could be used for mobility applications and it is anticipated that new technologies will appear permanently. For sure, the wireless connections among vehicles and between vehicles and infrastructure will play a pivotal role for the first embodiment of IoT for cars. It may be worth mentioning that a wireless connection is not in itself sufficient to evoke the IoT paradigm. Considering vehicles as things, IoT can be considered glue between the vehicle and the outer world, offering, from case to case, a proper management and monitoring (abstraction) interface. Additionally, each car is expected to become more and more a cluster of things – rather than just a thing: in fact, in future, a plethora of on-board, mutually connected, devices are likely to be either integrated in the car or to accompany a driver.

ERTICO has released two comprehensive reports on communication technologies for future C-ITS (Cooperative Intelligent Transport Systems) service scenarios [12] where e. g. definitions, standards, scenarios etc. have been collected to promote the usage of complementary and appropriate communication technologies. Furthermore, ETSI has released a Technical Report on Intelligent Transport Systems in terms of vehicular communications, a basic set of applications, and definitions[13].
The ERTICO report aims at providing recommendations for the roll-out of C-ITS services. The focus of the report is on how appropriate usage of communication technologies would increase the quality of mobility services, its safety and reliability, while minimising costs. Interoperability would contribute to this goal by ensuring the functioning of the applications envisaged as part of the EU transport policies across national borders. The report concludes that to maximize return of investment in C-ITS useful data captured in any (sub-) system should be made available to all relevant stakeholders by all available communication channels. In this context, privacy and security must be safeguarded.

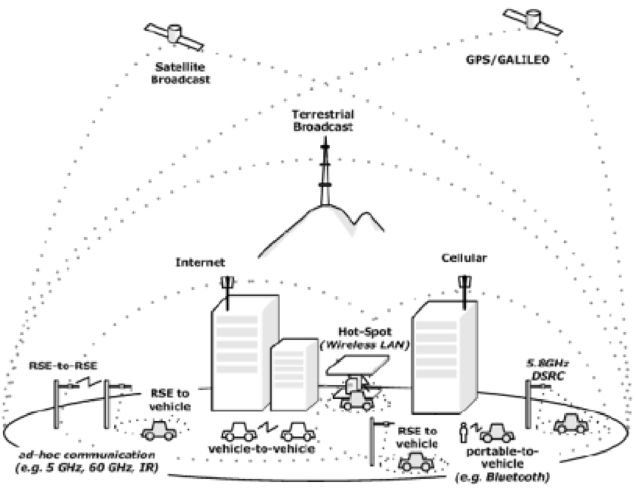

Fig.2: Smarter mobility via communication technologies

A proper infrastructure is needed to support communications in road transportation, regarding the new mobility patterns to come in future rural and urban scenarios. Standardization organizations such as ETSI and ISO are currently working in the definition of the networked framework depicted in Figure 2. Vehicles, infrastructure and pedestrian will be all connected to an ITS network where to access safety, efficiency and infotainment services.

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[12] http://erticonetwork.com/ertico-releases-guide-about-technologies-for-future-c-its-service-scenarios
[13] ETSI TR 102 638 V1.1.1 (2009-06)

The WG acknowledges the definitions of SAE J3016[14] for Automated Driving (see figure 3). Issued January 2014, the SAE provides a common taxonomy and definitions for automated driving in order to simplify communication and facilitate collaboration within technical and policy domains. It defines more than a dozen key terms and provides full descriptions and examples for each level. The focus of IoT aspects lies on automated driving level 3-4. This definition is also used by ERTRAC (European Road Transport Research Advisory Council), which is the central European stakeholder organization for Road Transport Research.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure 3: Levels of Driving Automation for On-Road Vehicles according to the SAE

3 Mapping of existing initiatives in the relevant area of the WG

3.1 European Technology Platforms and related initiatives, projects

ERTRAC, the European Technology Platform for Road Transport Research, has compiled the Automated Driving Roadmap (July 2015)[15]. This roadmap is the result of a one-year effort by ERTRAC to bring together industry representatives, research providers and national authorities and is meant as a reference for future actions to deploy automation in road transport.

This document provides an overview on the current status for automated driving technologies with regard to implementation in Europe. The ERTRAC roadmap is based on available documents for automated driving. The overall objective is to identify challenges for implementation of higher levels of automated driving functions. A lot of work has been done on this topic by various stakeholders and multi-

[14] http://standards.sae.org/j3016_201401

[15] http://www.ertrac.org/uploads/documentsearch/id38/ERTRAC_Automated-Driving-2015.pdf

stakeholders platforms (e.g. iMobility Forum, EUCAR, CLEPA, ERTICO, and EPoSS) and in European research projects. Therefore, it is essential to avoid any duplication of activities and concentrate on the missing items, concerns and topics for future implementation. The roadmap includes:

- Common objectives achievable thanks to automated driving
- Common definitions for the progressive levels of automation and the current and future systems
- A state of the art listing the past and currently running European projects
- An overview of national initiatives in the EU and around the world
- Key challenges and objectives for R&D and deployment activities
- A set of roadmaps describing the activities needed, from technological research to pilot testing, up to industrialisation, and including the regulatory adaptations

The ERTRAC roadmap included input from the European Technology Platform on Smart Systems Integration (EPoSS) which has produced the European Roadmap „Smart Systems for Automated Driving"[16]. These recommendations will be taken into account when defining the LSP and associated use-cases. Apart from the required technological advances in the sensor systems, environmental and driver monitoring, or communications, one of the major recommendation is to create more advanced field operational tests in order to demonstrate components and systems associated with safety, security and reliability within the highly automated driving at levels 3 and 4. This paves the way for the deployment of LSPs and offers synergies with other initiatives within and outside AIOTI focussing on e. g. policy, legal framework, etc.

In terms of the existing initiatives in the field, they are still mostly fragmented within different countries and companies and funded by national governments, framework programs or individual companies in the automotive field.

3.2 Horizon 2020

A large number of research and development initiatives funded by EC are active and can be split into four major areas namely robot car, driver assistance systems, connectivity and communications and networking challenges (see attachment 1). Currently, there are around ten such projects split between these areas each one addressing particular issues in the related domain and planning associated demonstrators. One particular example is AdaptIVe[17] project which aims to develop various automated driving functions for SAE levels 1 to 4 for daily traffic by dynamically adapting the level of automation to situation and driver status. Furthermore, the project addresses legal issues that might impact successful market introduction. The project plans eight different demonstrators where there are two classes of vehicles: passenger cars and heavy load trucks. Different types of passenger cars will be tested, ranging from city cars to larger passenger cars.

A next step in automated driving is the addition of communication technologies to improve the perception offered by autonomous systems powered by sensors such as radars or vision. There are several initiatives at international level which for the moment pave the way towards the integration of cooperatives services such as the automated driving. The ITSSv6 project[18] has recently concluded with the development of a communication stack compliant with current ISO and ETSI standards in cooperative ITS. It is particularly focused on the usage of IPv6 as a common protocol for vehicular communication nodes. This approach is clearly beneficial for the inclusion of IoT communication patters, given the global connectivity of nodes, even the embedded ones. ITSSv6 successfully integrated Internet of Things (IoT) devices into the ITS Station Reference Architecture defined by ISO/ETSI, which allowed ITS stations to communicate with

[16] http://www.smart-systems-integration.org/public/documents/publications
[17] AdaptIVe, https://www.adaptive-ip.eu
[18] ITSSv6 project, http://itssv6.eu

low-power sensor networks over IPv6 (6LoWPAN). This was successfully demonstrated at the 2012 ITS World Congress in Vienna, along with several other ITS communication technologies such as IEEE 802.11p and 3G.

In the same line, the FOTsis project[19], which is being finalised at the moment, has ported the communication stack of ITSSv6 to create a communication architecture appropriate for C-ITS services in the short term. It is, with no doubt, a key proof of concept of the guidelines given by ISO and ETSI regarding the reference ITS communication architecture. In contrast with other international initiatives, FOTsis bet on using well-known IETF protocols in the ITS sector, embracing the forthcoming all-IP world and the integration of vehicle subsystems in the IoT (Internet of Things) expansion to consumer devices. Hence, IPv6 is found the cornerstone for sticking two independent and huge partitions of the new era of the information and communication technologies: the Internet 2.0 and the car.

3.3 C-ITS Deployment Platform

The Commission has decided to take a more prominent role in the deployment of cooperative systems and has set up the C-ITS Deployment Platform in 2014, conceived as a cooperative framework including national authorities, relevant C-ITS stakeholders and the Commission, in view to provide policy recommendations for the development of a roadmap and a deployment strategy for C-ITS in the EU and identify potential solutions to some cross-cutting issues. The platform addresses the main barriers and enablers identified for the deployment of C-ITS in the EU. The C-ITS platform is expected to identify and agree on how to ensure interoperability of C-ITS across borders and along the whole value chain.

3.4 ECSEL - Electronic Components and Systems for European Leadership

Electronic Components and Systems for European Leadership (ECSEL) is a joint funding initiative of the European Commission, EU member states, and three private industrial associations (EPoSS, AENEAS, and ARTEMISIA)[20]. The programme of the ECSEL JU is designed to provide valuable Key Enabling Technologies, components and competencies allowing the community of R&D&I actors, alongside other existing programmes on ICT and related technologies in Europe, to benefit from new opportunities. Insofar, ECSEL is complementary to the other programmes.

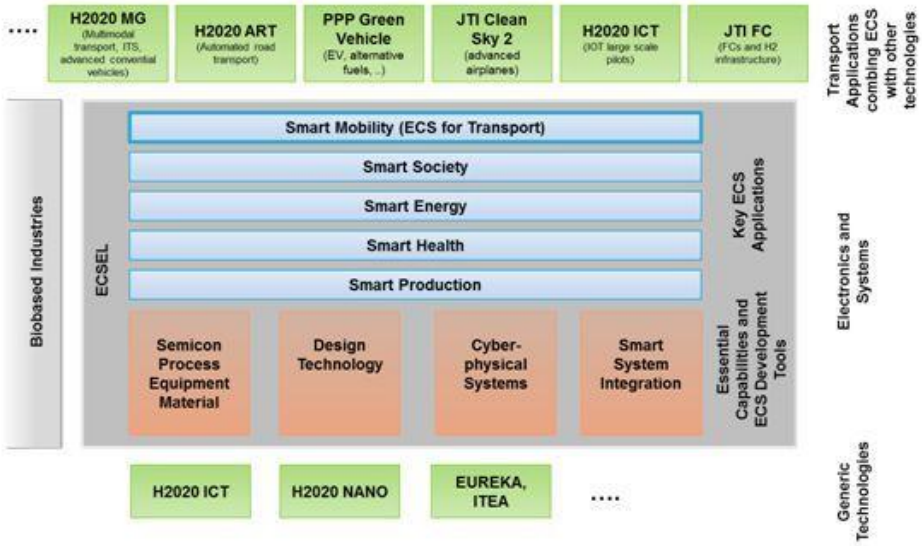

Figure 4: Relation of ECSEL Smart Mobility with other EU Research Programs[21]

[19] FOTsis project, http://www.fotsis.com
[20] www.ecsel-ju.eu
[21] 2016 Multi Annual Strategic Research and Innovation Agenda for ECSEL Joint Undertaking

ECSEL aims at delivering new revolutionary functionality of Electronic Components and Systems (ECS) to application-oriented Horizon 2020 transport research programmes like ”Mobility for Growth”, “Automated Road Transport”, or the IoT Large scale Pilots, where ECS are combined with mechanical, chemical material and other application-oriented research to solve EU transport problems. On the other hand, ECSEL continues to develop more advanced electronic components and systems including the underlying embedded software, and uses results of application oriented projects (e.g. automated vehicles, electric vehicles) as validation platforms. Therefore interactions between ECSEL and application-oriented programmes will continue in future loops.
As ECSEL application domains take advantage of cross domain electronic technologies, the smart mobility research programme expects research results from horizontal ECSEL capabilities as semiconductor processes, equipment and material, design technologies, cyber physical systems technologies and smart system integration.

3.5 Important Project of Common European Interest (IPCEI)

The High Level Group on Key Enabling Technologies[22] recommended to the European Commission and Members States to use large scale funding instruments like Important Project of Common European Interest (IPCEI) in strategic industrial domains such as “Connected & Automated Driving”. The European Commission highlighted the importance of this new funding instrument and gives guidance on the implementation of IPCEIs.[23] An IPCEI is a state-aid instrument to facilitate Member States, EU, and industry co-financing. Important criteria include for example:

- Significant impact on Union objectives and involve more than one Member State
- Spill-over effects: benefits are wider than participating sectors
- R&D&I projects must be of a major innovative nature
- Projects comprising industrial deployment must allow for the development of a new product or service and/or innovative dimension of a fundamentally innovative production process
- Co-financing by the industry

Many stakeholders promote the idea to build on existing activities at all levels and use an IPCEI to realize an integrated European strategy for “Connected & Automated Driving” by combining private and public efforts and financial resources in a transparent, state aid consistent way.

3.6 Main SDO, Alliances & Open Source initiatives

The main SDO/Alliances that are focusing significantly on Smart Mobility vertical industry domain are: CENELEC, Ca2Car Communication Consortium (C2C-CC), SAE International, CIA, ERTICO, Car Connectivity Consortium, ISO, Open Automotive Alliance (OAA), , Industrial Internet Consortium (IIC), AIOTI, IEEE, ETSI

The main SDO/Alliances that are focusing on the horizontal industry domain and can be as well applied in the Smart Mobility vertical industry domain are:
OSGi Alliance, Hyper/CAT, IETF, Thread, ISO/IEC JTC1, BBF, W3C, ITU, GSMA, OneM2M, OASIS, WWRF, 3GPP, OMG, LoRA, eClass, Bluetooth, Weightless, OGC, ipSO Alliance, OMA, Zigbee Alliance, The OpenGROUP

[22] http://ec.europa.eu/growth/industry/key-enabling-technologies/european-strategy/high-level-group/index_en.htm
[23] European Commission (2014/C 188/02)

3.7 FIWARE

FIWARE[24] project funded by European Commission under the FI-PPP programme[25] aims to advance the Europe's competitiveness' within the Future Internet and IoT domains in general and to stimulate the growth in different verticals such as transport, media, health and others. The overall programme has been financed with around 600 million euros with 158 organisations taking part from 21 countries from around Europe and 2 more from outside of Europe. The programme has been split into 3 distinct phases with the first phase starting in 2011 and completing in 2013. The aim of this phase was to develop the underling core technology and to define the use-cases. Second phase, running 2013-2015 concentrated on developing the use-case pilots and associated platforms. This phase has overlapped with the currently running phase 3 which has started in 2014 and it will run until 2016. The main focus of this phase is to develop commercial products based on the FIWARE technology through the 16 FIWARE accelerator programmes for start-up companies. Different activities within the projects are active, such as the catalogue of all the components, FIWARE Lab providing the non-commercial sandbox environment for prototyping and experiments and FIWARE Ops containing the set of tools easing the deployment and development with enablers. In the context of the Smart Mobility WG, this project is of great importance as pilot deployments within the LSP can leverage the technology for most of the core functionality that is required in the IoT domain. Other specific requirements, features and proprietary components can be federated on top of this core infrastructure installation.

3.8 National Organisations & Initiatives

On top of the initiatives above, there are number of national strategies in this domain such as in France set out by the government[26] that will contribute to the development of a new industrial France including the automated driving until the year 2020. Furthermore, in Germany, recently formed "Round Table Automated Driving"[27], organised and led by the German Federal Ministry of Transport and Digital Infrastructure, addresses the issues related to legal frameworks, infrastructure and technological requirements of automated driving. This organisation brings together the experts from different fields that are very important in the domain of automated driving including politics, insurance, vehicle manufacturers and suppliers as well as research institutions. In the UK, at the end of July 2014 the government announced two new measures that would initiate "the green light to driverless cars" on UK roads aimed at the cities to compete for the funding (£10 million GBP) to launch driverless car trials.
The Dutch EU Presidency in 2016 will put innovation in transport as a clear focus of the discussions in EU's policy, in particular highly automated and connected vehicles. Already, one very visible example is the European Truck Platooning Challenge 2016[28].

3.9 Company initiatives

Apart from the most prominent demonstration from Google, European companies are also making an impact with practical initiatives showing the developments within the automated driving industry. These companies include Daimler demonstrating autonomous driving on the public road from Mannheim to Pforzheim with a Mercedes-Benz prototype car equipped with production-based technologies for autonomous driving. Furthermore, the same company have demonstrated so called Future Truck which runs without the driver and is being completely supported by numerous assistance systems. Other company actively involved in the field demonstrators is Renault who have demonstrated autonomous valet parking technology with an electric vehicle using automotive sensor components to run in auto-pilot mode without passengers from a drop-off area to a parking lot or wireless charging station and vice versa.

[24] FIWARE project, http://www.fiware.org
[25] EC FI-PPP Programme, https://ec.europa.eu/digital-agenda/en/future-internet-public-private-partnership
[26] "La Nouvelle France industrielle," http://www.economie.gouv.fr/nouvellefrance-industrielle.
[27] "Runder Tisch zum Autonomen Fahren," http://www.autonomesfahren.de/runder-tisch-zum-autonomen-fahren
[28] www.government.nl/topics/mobility-public-transport-and-road-safety/contents/european-truck-platooning-challenge-2016

4 Investigation of the technological dimension for the large scale pilot

The successful deployment of safe and automated vehicles (up to SAE level 5) using IoT technology in different use case scenarios, using local and distributed information and intelligence is a very challenging task. This is based on real-time reliable IoT platforms managing mixed mission and safety critical vehicle services, advanced sensors/actuators, navigation and cognitive decision-making technology, interconnectivity between vehicles (V2V) and vehicle to infrastructure (V2I) communication. The IoT LSP needs to demonstrate in real life environments like mixed traffic conditions the functionalities in order to evaluate and demonstrate dependability, robustness and resilience of the technology over longer period of time and under a large variety of conditions.

The introduction of the automated vehicles will enable the development of service ecosystems around vehicles and multi-modal mobility, considering that the vehicle includes multiple embedded information sources around, which information services may be constructed. The information may be used for other services (i.e. maintenance, personalized insurance, vehicle behaviour monitoring and diagnostic, security and autonomous cruise, etc.). However it will be necessary to enable data exchange based on equal access and standardized interfaces. Open Platforms and standardised interfaces are necessary for the automotive value chain to allow access to relevant data to optimize products and services and an open cloud environment could be a starting point for a new era of digital business in Europe[29]. To enable competition in the market of vehicle based IoT services, consumers must have the opportunity to give consent and to select the provider of their choice. This again, could be part of an Open City Platform (which might be built on FIWARE Generic Enablers) with aggregated data from all mobility stakeholders.

A LSP has to consider the infrastructure for autonomous vehicles for transport and delivery and for supporting autonomous system integration and acceptance using a coordinated deployment approach (e.g. system density and standardization), standardized architecture development. In this context elements that will be addressed are autonomous vehicle control systems and behaviour algorithms; interconnected vehicle and fixed sensing modalities; system optimization planning, simulation and modelling tools; human-machine interfaces; and trusted communications and standardized interfaces and protocols

Intra vehicle communication infrastructure for V2G, V2I, V2V integrating the vehicle as a communication and computing platform are an important part of the IoT LSP considering high-speed low latency network infrastructure using Ethernet backbone architecture, in vehicle gateway(s) – convergence, V2X communication (i.e. 3G/4G, IEEE 802.11p, Wi-Fi standard, etc.), edge cloud communication to traffic clusters and infrastructure to vehicle via digital broadcast media.

4.1 Use cases

In general, the different areas for new smart mobility car services can be grouped into five main use case categories:

- Automated driving, for example: automated valet parking, cooperative collision avoidance, high density platooning
- Road safety and traffic efficiency services, for example: Vulnerable Road User (VRU) Discovery, See-through, Bird’s Eye View
- Digitalization of transport and logistics, for example: Remote sensing and control, Remote processing for vehicles
- Information society on the road, for example: Smart Parking, nomadic vehicle nodes for extending network coverage

[29] http://www.converge-online.de/?id=000000&spid=en

Automated driving in cities is an extremely complex task and has features that are very different from e. g. autonomous robots in agriculture and different from automation on highways, even if speed is much slower and some hardware devices are similar. For example, roads inside the city will not always have well painted line marks on the ground, GNSS sensors is also less accurate as satellites can be occluded or because of multi-target signal path. Environment is also “open” and autonomous vehicles should address vulnerable users (pedestrian, bicycles, etc.) that may appears at any time around the vehicle.

ETSI has summarized an overview of use case to be considered in the further evaluation of the LSP (see figure 5[30]). Selection of these cases has to take into account requirements and needs from users and stakeholders in different criteria:

- Strategic requirements like minimum market penetration or valuable customer' service
- Economical requirements like purchase and operating costs or return on investment
- System capabilities requirements like radio or network communication capabilities
- System performances requirements like vehicle communication or positioning performances
- Organizational requirements like the availability of a common, consistent applications/use cases addresses directory or of an IPv6 address allocation scheme usable for V2V/V2I communication.
- Legal requirements like customer' life privacy or liability
- Standardization and certification requirements like system interoperability testing

Applications Class	Application	Use case
Active road safety	Driving assistance - Co-operative awareness	Emergency vehicle warning
		Slow vehicle indication
		Intersection collision warning
		Motorcycle approaching indication
	Driving assistance - Road Hazard Warning	Emergency electronic brake lights
		Wrong way driving warning
		Stationary vehicle - accident
		Stationary vehicle - vehicle problem
		Traffic condition warning
		Signal violation warning
		Roadwork warning
		Collision risk warning
		Decentralized floating car data - Hazardous location
		Decentralized floating car data - Precipitations
		Decentralized floating car data - Road adhesion
		Decentralized floating car data - Visibility
		Decentralized floating car data - Wind
Cooperative traffic efficiency	Speed management	Regulatory / contextual speed limits notification
		Traffic light optimal speed advisory
	Co-operative navigation	Traffic information and recommended itinerary
		Enhanced route guidance and navigation
		Limited access warning and detour notification
		In-vehicle signage
Co-operative local services	Location based services	Point of Interest notification
		Automatic access control and parking management
		ITS local electronic commerce
		Media downloading
Global internet services	Communities services	Insurance and financial services
		Fleet management
		Loading zone management
	ITS station life cycle management	Vehicle software / data provisioning and update
		Vehicle and RSU data calibration.

Figure 5: Overview of use cases by ETSI[18]

[30] ETSI TR 102 638 V1.1.1 (2009-06)

Looking at the basic set of applications ETSI list a set of use cases as a matter of appropriate examples:

- Collect real-time and up-to-date travel information on current road congestions, road works and taxi or public transport availability to enable efficient and optimised navigation services, including multi-modal transportation alternatives (e.g. vehicle-sharing and public transport);
- Ease logistic services (e.g. reservation of loading / unloading bays, temporary parking, assisted navigation to entrance / exit gates, etc.) by means of timely transmission of dedicated information to heavy trucks in complex points of interest (as sea ports, airports, etc.);
- Improve the ease of charging electrical vehicles, by providing information about the availability of charging stations nearby and allow user to pay automatically for the electricity they have used;
- Improve the last mile reachability by equipping public bikes with tracking devices and keyless bike locks to enable easy bike sharing;
- Enable locating and automatic paying for the best, available parking spots (related to price, distance, safety, etc.) nearby the destination and allow elderly or disabled individuals to reserve those spots in advance;
- Allow individuals to rent their privately-owned parking spots to other drivers when they are not using them and improve the ability of public services to detect illegally parked vehicles.
- Create an open data platform with (big data analyses on) usage statistics, travel information, road congestions, public transport timetables, accidents, road works, etc. to improve decision making, traffic management and allow external developers in creating value-added services; and
- Automated electronic and usage based payment of road, insurance, public transport and parking spots with pricing dependent on road congestion, carpooling and driving behaviour.

The development of IoT applications for automated vehicles can aim at:

- Use IoT platforms and the edge cloud facilities to store, update and retrieve needed models, maps, data for autonomous driving,
- Connect the autonomous vehicle to the IoT platforms, including deporting intelligence on other IoT applications infrastructure (i.e. buildings, energy for EVs, city, etc.).
- Propose new perception and analysis systems
- Secure communication, authentication and services when connecting the vehicle.
- Advanced control algorithms for collision avoidance. Secure cooperative communications' implementation in autonomous driving applications (i.e. PRT, platooning) covered by the use of specific cryptographic methods

4.2 Requirements and Criteria for Large Scale Pilots

There are several important aspects that should be covered in all test scenarios to ensure the deployment of connected automated driving like safety, reliability, security, or privacy. The WG has compiled a set of helpful criteria. Of course, a given LSP may not fulfil all criteria to the largest possible extent:

Non-Technical Criteria

- European & societal value
- User attractiveness & new services for user
- Contribution to automated driving
- Compliance with existing regulations
- Societal & economic impact
- Benefit to mobility efficiency through IoT
- Multiservice platforms
- Standardization and compatibility with existing technologies
- Multi eco-systems
- Sustained value chains
- Legal and liability issues in the supply chain

Technical Criteria

- High Technology Readiness Levels
- Co-modality
- Interoperability
- Modularity
- Scalability and replicability
- Security and safety
- Data integrity and reliability
- Roadworthiness
- Deploy intelligence and functionality across the processing resources (sensors, gateways, etc.)
- Data handling (fusion, cleaning, processing, mining, etc.)

4.3 Common standards and specifications

The use case can largely be built on common standards and[31]:

- Wireless and automated payment can be done by the use of smartphones and smart cards with RFID and/or Near Field Communication and the Calypso electronic ticketing standard;
- Real-time road usage information exchange can be achieved using the DATEX II or CEN SIRI standards and the initiatives around the INSPIRE data specifications with TN-ITS/ROSATTE on ITS-related spatial data
- Positioning vehicles and public bikes can be done by using GPS/Galileo devices
- Automated road tolling can be achieved with technologies in the European road tolling standard, such as Dedicated Short Range Communication (DSCR), Automated Number Plate Recognition (ANPR) or the Global Navigation Satellite System (GNSS)
- Automated notification of emergency services can be done with the eCall standard
- Cloud platform connectivity can be achieved with networking services, such as 3G/LTE, WiMAX, MobiquiThings or Sigfox/LoRa.
- Networking services towards vehicles can be achieved making use of the IEEE802.11p standard as a part of the G5 protocol suite standardized by ETSI;
- Parking spot availability (as well as infrastructure monitoring) can be checked using a wireless sensor network complying withIEEE802.15.4 technology for Physical and MAC layers, and IETF 6LoWPAN/CoAP for Networking and Facility layers;
- Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication services can be achieved with technologies like 3GPP LTE-V2X (Vehicle Direct Communication through proximity services) or 802.11p

The R&D initiatives centered on "Connectivity and Communication" focus on the design and development of a fully networked car integrated with an Intelligent Transport System. The European frequency band allocation (Commission Decision 2008/671/EC) was followed in October 2009 by an EC standardization mandate (M/453) to support European Community wide implementation and deployment of Co-operative ITS systems. These standards[32] have been published by ETSI TC ITS and CEN TC 278 in February 2014 and also includes standardized testing procedures to be carried on in labs and open-air testing environments. Other Standards Development Organizations (notably ISO within the activities carried on by TC 204) are also contributing to spread and consolidate networking and applications protocols in Intelligent Transport Systems.

[31] Source: See footnote 1
[32] ETSI TR 101 607 V1.1.1 (2013-05)

5 Recommendations for the testing of business models and of user acceptability

It is expected that in the scope of the LSP only a dedicated subset of applications and use cases is evaluated which reflects innovative services which provide additional value. Evaluating the benefits provided by the IoT technologies will be therefore critical for all stakeholders. The usefulness and the potential benefits, expected out of new technologies should be assessed from three different perspectives:

- The economic evaluation
- The user acceptance
- Performance evaluation

5.1 The economic evaluation

The economic evaluation is important considering the significant investment necessary to involve IoT technologies in the context of smart mobility scenarios. The investments necessary to deploy IoT in the domain of smart mobility need to pay off for the automotive industry as well as for the society. The economic evaluation should therefore be considered from two different perspectives.

- The industry perspective, where the adoption of new technologies is only considered if it provides return on investments within a reasonable time frame. This type of evaluation requires developing and evaluating business models.
- The societal benefit is evaluated by the mean of socio economic impact analysis. It aims at providing evidence concerning the usefulness of new technologies with regards to their overall costs from the user but also from the public point of views.

5.2 The user acceptance

New technology can only be considered as useful if they are fully accepted by the final users. Therefore user acceptance is a key criterion for the success of new technologies. User acceptance means that the new technology brings sensible and visible to the user but also does not provide neither harmful nor negative impact for the daily use of the mobility means involving the IoT technology.

In the specific context of IoT, user acceptance may not focus on the direct perception of the benefit from the IoT technology, which is likely not to be detected by the user. The indirect benefit will therefore be more critical. In the context of the possible negative impacts, the issues relating with security and privacy will be a strong focus.

Furthermore, due to the increasing amount of assistant services including e.g. Infotainment services it is essential for the acceptance that the end user does not get overwhelmed by the usage with different services. This evaluation in context with other services is also most relevant for the business evaluation, i.e. when parts of an existing infrastructure can be shared for different services.

5.3 Performance evaluation

Performance evaluation involves the testing of the system in terms of performance figures of merit. For this, a proper methodology is required, covering preparation and test execution stages. First, it is required to specify the testing scenarios, considering: the scenario for the case of study, taking into account the technologies to be tested and the expected capabilities; a detailed description of the tests to be done, considering data flows, movement of terminals, physical conditions, etc.; a definition of the performance metrics to be analysed during tests, in order to save relevant data; and a specification of the needed software tools to both log performance metrics during tests and carry out post-processing tasks. Finally, a wide set of tests should be covered, to provide statistical information to the results.

6 Investigation of the operational dimension for the large scale pilot

The emergence of automated vehicles in the IoV and IoT applications will generate new services that will be supported by open IoT service platforms that communicate and exchange information with the vehicle embedded information sources and to vehicle surrounding information, with the goal of providing personalised services to drivers. Possible barriers to the deployment of autonomous vehicles and ecosystems such as the robustness sensing/actuating the environment, overall user acceptance, the economic, ethical, legal and regulatory issues have to be analysed and evaluated during the lifetime of the IoT LSP. The LSP is expected to prove an effective convergence of automated driving and cooperative ITS technologies. In addition, LSPs should be able to show or describe the scenario(s) how usually limited pilots could be efficiently spread to other regions after the LSP successfully prove the basic concept. The call itself[33] requires to prove the effectiveness of autonomous and assisted driving by "mixing autonomous connected vehicles and legacy vehicles".
However, it is very important to note that no LSP for Level 5 automated driving can be realized within the next years. Driverless vehicles in restricted areas are by definition Level 4, because Level 5 would mean to go from any point A to any point B in mixed traffic conditions without any interruption. Therefore, any LSP needs to focus on Level 3-4 and to support IoT technologies for future Level 5 automation.

6.1 Smart Sea Ports

Closed or restricted environments could be more suitable to demonstrate the impact of the autonomous driving technologies on transport ecosystems. For example, “gateway” sea ports show a fine combination of best-in-class ITS technologies (i.e. ICT solutions to support huge figures of freight traffic) and restricted access zones (truck parking, containers terminal areas for container shipping, etc.) where demonstrating autonomous driving technologies is feasible. Self-driving vehicles in “gateway” sea ports have the ability not just to transport goods, but also to combine other process steps, such as cargo loading and unloading, in order to increase the sustainable efficiency of the entire process.
Moreover, inside a corridor-wide Port Community System the self-driving vehicles will be one of the choices offered between a range of transport modes at a given time by the port logistic infrastructure. The opportunity to dynamically select the best carrier, including autonomous drived vehicles to move freight to the next node of the supply chain will be demonstrated on the basis of cost and environmental impact, according to the policies of the IoT enabled synchro-modal supply chain.

6.2 Smart Parking – Automated Valet Parking

Automated Valet Parking (AVP) allows parking your vehicle at a drop zone. The vehicle will be autonomous guided and parked to a free parking lot. If the driver needs the vehicle, it also drives autonomous back to a pickup zone. All this by using a smartphone app. AVP is possible thanks to the IoT based combination of an intelligent infrastructure in the car park and vehicle based technologies in conjunction with on-board sensors. The scenario is conceivably simple:

- The driver drops off his vehicle in front of an AVP parking garage, gets out, and initiates the automated parking procedure with his smartphone.
- Meanwhile the vehicle establishes a secure network connection with the parking garage and receives the required information for parking.
- The driver-less vehicle manoeuvres to and into the designated parking space.

[33] HORIZON 2020 - Work Programme 2016 - 2017 Cross-cutting activities (Focus Areas), IoT Large Scale Pilot 5): https://ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/17.%20CROSS%20CUTTING_2016-2017_pre-publication.pdf

- The smartphone notifies the driver that his vehicle has been parked successfully
- The driver chooses a pick-up time on his smartphone and AVP steers the vehicle to a pick-up zone where the driver can take over again.

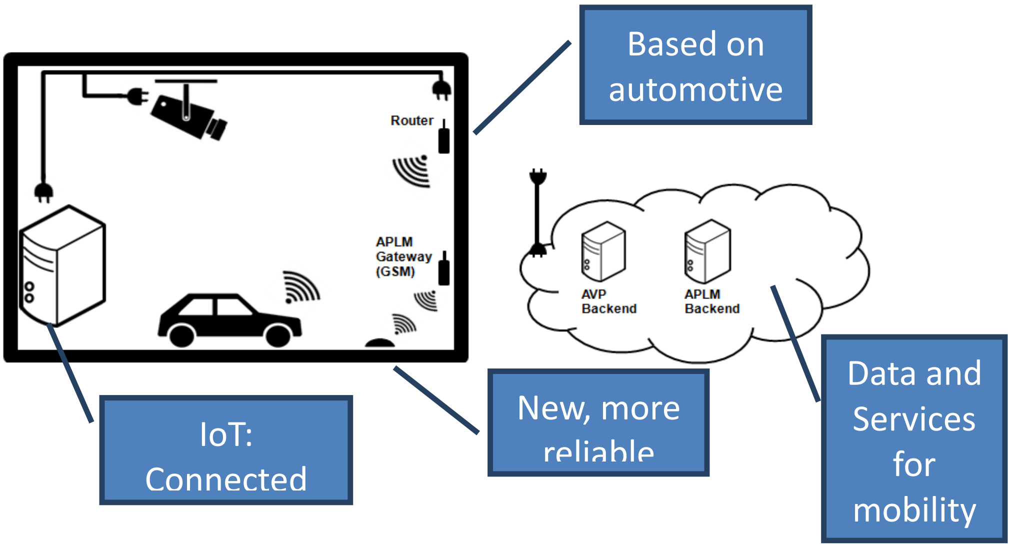

Figure 6: Technologies for Automated Valet Parking

7 Next steps

In Dec. 2015 the next AIOTI WG meeting for further open discussion of possible LSPs is planned. In order to disseminate the findings among public and private stakeholders it is suggested to have an active participation at a number of public workshops, information days and conferences.
Suitable events for dissemination are for example:

- FIA Conference 20 Oct. 2015
- Automotive Europe 2-3 Nov. 2015
- ERTRAC Info day 6 Nov. 2015
- EU Info day (Dec. 2015, tbc)
- CESA Automotive Electronics, 2016

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9 Appendix 1: List of European projects in Connectivity & Communication for Automated driving[34]

Category	Acronym	Name	Duration	Purpose / Keywords
Connectivity & Communication	**COM2REACT**	Cooperative Communication System to Realise Enhanced Safety and Efficiency in European Road Transport	01/2006 12/2007	Road and in-car communication systems, cooperative system, involvement of two-way communication systems: V2V and V2I, contribution for standardization and harmonization throughout Europe
	SAFESPOT	Cooperative Systems for Road Safety	02/2006 01/2010	Implementation and demonstration of V2V-based technology, Local Dynamic Maps, multi-sensor data fusion
	COOPERS	Co-operative Networks for Intelligent Road Safety	02/2006 - 01/2010	Development of intelligent transport systems (ITS), I2V technology, co-operative traffic management
	CVIS	Cooperative Vehicle-Infrastructure Systems	07/2006 - 06/2010	Development of a technology platform that provides wide-ranging functionality for data collection, journey support, traffic and transport operations and driver information.
	Intersafe-2	Cooperative Intersection Safety	06/2008-05/2011	Development of a Cooperative Intersection Safety System (CISS) – detection of static and dynamic components of the traffic environment.
	ISI-PADAS	Integrated Human Modelling and Simulation to Support Human Error Risk Analysis of Partially Autonomous Driver Assistance Systems	09/2008-08/2011	Joint Driver-Vehicle-Environment Simulation Platform, prediction of driver errors in realistic traffic scenarios, driver modelling, Human Error Risk Analysis
	SARTRE	Safe Road Trains for the Environment	09/2009-10/2012	Development of strategies and technologies allowing vehicle platoons to operate on public highways – introduction of the vehicle platoons concept
	DRIVE C2X	DRIVing implementation and Evaluation of C2X communication technology in Europe	01/2011-07/2014	Creation of harmonized Europe-wide testing environment for cooperative systems, promotion of cooperative driving
	79GHz	International automotive 79 GHz	07/2011-06/2014	Global harmonization, 79GHz band, automotive short-range radars

[34] http://www.ertrac.org/uploads/documentsearch/id38/ERTRAC_Automated-Driving-2015.pdf

		frequency harmonization initiative and worldwide operating vehicular radar frequency standardization platform		
	FOTsis	European Field Operational Test on Safe, Intelligent and Sustainable Road Operation	04/2011-09/2014	Intelligent transport systems, electronic stability control, cooperative I2V & V2I technologies, emergency management, safety incident management, intelligent congestion control, dynamic route planning, infrastructure safety assessment
	ARTRAC	Advanced Radar Tracking and Classification for Enhanced Road Safety	11/2011-10/2014	Generic detection system, detect low-friction road sections, automatic braking, VRU safety technologies, radar hardware, software and performance-related algorithms
	Compass4D	Cooperative Mobility Pilot on Safety and Sustainability Services for Deployment	01/2013-12/2015	Forward collision warning (FCW), red light violation warning (RLVW), energy efficient intersection service (EEIS), cooperative system, standardization cooperation
	AMiDST	Analysis of Massive Data STreams	01/2014-12/2016	Big data, stream processing, software development, automotive

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