C-ITS communication: an insight on the current research activities in the European Union

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Abstract: - Cooperative-Intelligent Transportation Systems aim at connecting vehicles, among them and/with road infrastructures, so as to increase traffic safety and efficiency. The paper focuses on the European framework for supporting the development of Cooperative, Connected and Automated Mobility, in order to provide an overview about the current status of testing and deployment activities in the field, in view of the milestone of 2019 which has been identified as the start time for the actual deployment of mature services. Therefore, firstly, the European strategy is described and communication (collectively known as vehicle-to-everything) services, as well as related technologies, are discussed. Then, funded research projects across the Union are recalled and, finally, a critical discussion on the resulting picture is provided.

Key-Words: - C-ITS services, vehicular communication, V2X technologies, cooperative driving, EU C-ITS framework, European projects.

1 Introduction

Cooperative-Intelligent Transportation Systems (C-ITS) represent the set of technological and functional elements allowing specific communication tasks identified as V2X (i.e. vehicle to everything) communication services. Specifically, the '*X*' can identify another Vehicle (i.e. V2V communication) or the Infrastructure (i.e. V2I communication). The primary goal is the improvement of road safety, by helping the driver to take the right decision and adapt to traffic conditions avoiding potential harm. For example, vehicles connected among them and with infrastructure, by sharing their position and speed, could improve driver awareness of approaching potential dangers and strongly increase collision avoidance. This implies abating road fatalities and injury severity. Other potential benefits of the use of C-ITS include enhanced traffic efficiency and improved comfort driving. Indeed, by means of V2X technologies, it is possible to reduce congestion (by providing warnings for approaching traffic queues and suggesting alternative routes) and make driving tasks less reliant on human action. Finally, they can ensure environment-friendly driving through in-vehicle technologies (e.g. eco-driving), and smarter transportation management at the network level.

Within this framework, both the vehicle and the infrastructure have to be smart elements and a reliable communication channel between them needs to be built. Therefore, on one side, it is worth analysing the main C-ITS services and, on the other, the communication technologies adopted for implementing them. Obviously, according to the features of each C-ITS service (e.g. safety-critical vs. no safety-critical), a suitable communication technology needs to be adopted. It is worth noting that communication and cooperation between vehicles and between vehicles and infrastructure are crucial for the safe integration and operation of Automated Vehicles (AVs) in the future transport system.

The paper aims at providing a comprehensive overview of the current status of C-ITS testing and deployment activities, with particular attention to the European Union (EU) case. The goal consists in identifying which services are already mature and, therefore, ready to be deployed, against those requiring additional research and experimental phases. Moreover, a critical analysis is provided about the possible reasons why some tasks are still needed to be developed and tested with respect to those already consolidated.

The remainder of the paper is organised as follows: section 2 presents a wide description of the EU C-ITS strategy; section 3 and section 4 illustrate the investments EU is putting in action, respectively through the establishment of European consortia and the funding of research projects; finally, section 5 outlines the concluding remarks.

2 The European framework

The European Commission (EC) is making significant efforts in the field of C-ITS communication, in order to carry out a reference framework for supporting Cooperative, Connected and Automated Mobility (CCAM) policies [1].

The matter is quite complex since it presents several implications to be considered. Fig.1 outlines the EU framework for supporting C-ITS services development. In particular, first of all, the EU C-ITS strategy aims at developing a common vision on such a matter to be spread across the Union, so as to bring together efforts of the different involved stakeholders. For this purpose, the EC, in early 2014, set up the C-ITS Platform, conceived as a cooperative framework in view to develop a shared vision for the interoperable deployment of C-ITS in the EU. Later, in 2016, Member States launched the C-Roads Platform to link and coordinate C-ITS deployment activities across the Union. Finally, on completion of the picture, there are some legal issues to be addressed for ensuring legal certainty for public and private investors, handling the availability of EU funding and ruling the legal liability of the parties.

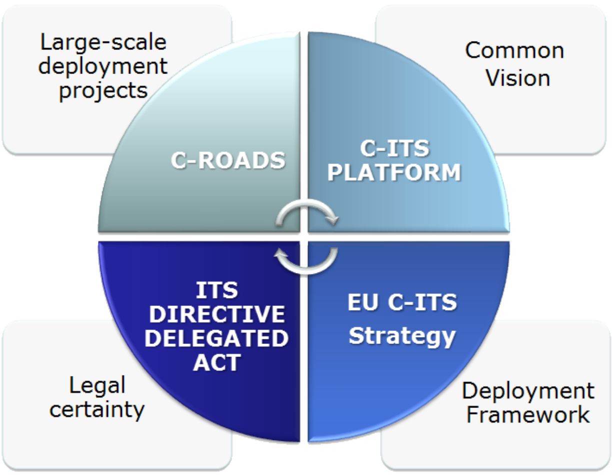

Fig.1 EU C-ITS framework (source [1])

However, the paper focuses on the technological and functional aspects of the matter, which essentially concern C-ITS services and adopted communication technologies.

Therefore, it is worth describing the C-ITS services outlined in the EU strategy. They are:

- *Emergency electronic Brake Light* (EBL): aimed at warning drivers of hard braking by vehicles ahead, thus preventing rear and longitudinal collisions. It is a safety-critical service.
- *Emergency Vehicle Approaching* (EVA): aimed at providing an early warning of approaching emergency vehicles, prior to the siren or light bar being audible or visible, thus allowing vehicles extra time to clear the road and, therefore, reducing the number of unsafe maneuvers. It is a safety-critical service.
- *Slow or Stationary Vehicle(s)* (SSV): aimed at warning approaching drivers about slow or stationary/broken down vehicle(s) ahead. It is a safety-critical service; however, it can also benefit traffic efficiency.
- *Traffic Jam ahead Warning* (TJW) aimed at providing an alert to the driver on approaching the tail end of a traffic jam. This can be particularly useful when, for example, the tail end is hidden behind a hilltop or curve. It is a safety-critical service; however, it can also benefit traffic efficiency.
- *Hazardous Location Notification* (HLN): aimed at giving an advance warning of upcoming hazardous locations in the road (e.g. sharp bend in the road, steep hill, pothole, obstacle, or slippery road service). It is a safety-critical service.
- *Road Works Warning* (RWW) aimed at informing drivers about current road works and related restrictions. It is a safety-critical service; however, it can also benefit traffic efficiency.
- *WeaTher Conditions* (WTC): aimed at providing accurate and up-to-date local weather information. This is particularly useful in the case of dangerous weather conditions difficult to perceive visually, such as black ice or strong gusts of wind. It is a safety-critical service.
- *in-Vehicle SGNnage* (VSGN): aimed at providing advance information about relevant road signs in the vehicle surroundings, thus increasing driver awareness. It is a safety-critical service.
- *in-Vehicle SPeeD limits* (VSPD): aimed at informing drivers about speed limits, continuously or on a specific occurrence (e.g. in the vicinity of road signs or when drivers do not comply with speed requirements). It is a safety-critical service; however, it can also benefit traffic efficiency.
- *Probe Vehicle Data* (PVD): aimed at collecting vehicle data for a variety of purposes concerning circulation safety and efficiency, traffic management, as well as environmental issues.
- *ShockWave Damping* (SWD): aimed at reducing the occurrence of traffic shockwaves (i.e.

transition zones between two traffic states that move through a traffic environment), thus making traffic flow smoother and decreasing vehicles emissions.

- *Green Light Optimal Speed Advisory (GLOSA) / Time To Green (TTG)*: aimed at providing speed advice to drivers approaching traffic lights, thus reducing the number of sudden acceleration or braking incidents. This is intended to optimise vehicle's movement, with benefit on traffic efficiency, vehicle operation (fuel saving) and environment.
- *Signal Violation/ Intersection safety* (SigV): aimed at reducing the number and severity of collisions at signalised intersections. It is a safety-critical service.
- *Traffic Signal Priority request by designated vehicles* (TSP): aimed at allowing drivers of priority vehicles (e.g. emergency vehicles, public transport, HGVs) to be given priority at signalised junctions. This service can benefit traffic efficiency and vehicle operation.
- *Infotainment services*: aimed at providing different kinds of information to the drivers. They can be further outlined as follows:
    - Information on fuelling & charging stations for alternative fuel vehicles (iFuel);
    - Off-street Parking information (Pinfo);
    - On-street Parking Management and information (PMang);
    - Park & Ride information (P&Ride);
    - Traffic information & Smart Routing (SmartR).

  They can provide significant benefits, for instance, in terms of reductions of vehicles emission by decreasing the time spent cruising at low speed for searching a parking space.
- *Loading Zone Management* (LZM): conceived for supporting the management of urban parking zones specific to freight vehicles, with benefits for drivers, fleet managers and road operators.
- *Zone Access Control for urban areas* (ZAC): aimed at providing information about access restrictions to specific urban areas, thus allowing drivers to better plan their trip.
- *Vulnerable Road User protection* (VRU): aimed at protecting vulnerable road users, i.e. pedestrian and cyclists. It is a safety-critical service.
- *Cooperative Collision Risk Warning* (CCRW): aimed at minimising the risk of collision during overtaking or merging with traffic. It is a safety-critical service.
- *MotorCycle Approaching indication* (MCA): aimed at warning drivers for arriving motorcycles. This is particularly useful, for instance, in the case of reduced visibility. It is a safety-critical service.
- *Wrong Way Driving* (WWD): aimed at providing an advance warning of wrong-way driving, thus alerting, on one side, the drivers that they are driving in the wrong direction and, on the other side, warning surrounding vehicles of the danger. It is a safety-critical service.
- *Connected and Cooperative Navigation* (CCN): it is an advanced C-ITS service in which tasks like 1st and last mile, parking information, route advice and coordinated traffic lights are synchronising and fully integrated into a systemic view. Clearly, its potentialities range from traffic safety and efficiency to environmental issues and vehicle operation tasks.

A more detailed description of the features and applications of the above-mentioned C-ITS services can be found in [2]-[10].

Obviously, each one of such services needs to be supported by standardised messages and suitable communication technologies.

Within this framework, the *European Telecommunications Standards Institute* (*ETSI*) has defined two different kinds of messages, namely *Cooperative Awareness Message* (*CAM*) [11] and *Decentralized Environmental Notification Message* (*DENM*) [12], with related packet formats and dissemination guidelines. Specifically, CAMs are a kind of heartbeat messages periodically broadcasted by each vehicle to its neighbors to provide information on the presence, position, speed, temperature and basic status. On the contrary, DENMs are event-triggered messages broadcasted to alert road users of a hazardous event. Both CAM and DENM messages are delivered to vehicles in a particular geographic region: to the immediate neighborhood, in case of CAMs (single hop), and to the area affected by the event for DENMs (multi-hop) [13]. Other two kinds of standardised messages, generally disseminate by the infrastructure, are *Signal Phase and Timing* (*SPaT*) and *Map Data* (MAP) [14]-[16]. The former concerns the status of a traffic controller, prediction of duration and phases, data elements for prioritisation response, as well as permissions linked to manoeuvres instead to lanes; the latter provides information about road topology (such as topological definition of lanes for a road segment or within an intersection, links between the segments and restrictions at lanes).

Further, V2X data exchange can occur by means of different kinds of technologies. The most mature communication technology is represented by the ETSI ITS G5 [17]. It is a European set of protocols and parameters for short-range communication between vehicles and traffic infrastructure operating in the 5.9 GHz frequency band. It is based on the IEEE standard 802.11 [18] (used also for Wi-Fi) and its amendment 802.11p on wireless access in vehicular environments [19], which introduces several modifications to adapt the Physical (PHY) layer and Medium Access Control (MAC) sub-layer to the requirements of highly dynamic vehicular environments. Up-and-coming alternative technologies are represented by cellular LTE [20] and cellular 5G [21] communications. As shown in Fig.2, the key difference is represented by the fact that cellular-based services need to rely on the presence of the cellular network. This makes exchanging data less immediate and direct, with respect to the ETSI ITS G5, and confines cellular options to non-safety-related V2X tasks. By contrast, ETSI ITS G5, with its low latency (less than 100 milliseconds), currently represents the most suitable technology for safety-related, time-critical C-ITS applications, where the rapid exchange of information may make the difference between life and death.
However, as shown by [23], across the Union has been installed several pilot sites in which also additional technologies are being tested for applications in the V2X communication fields, namely wi-fi, bluetooth, radio data and digital audio broadcasting.

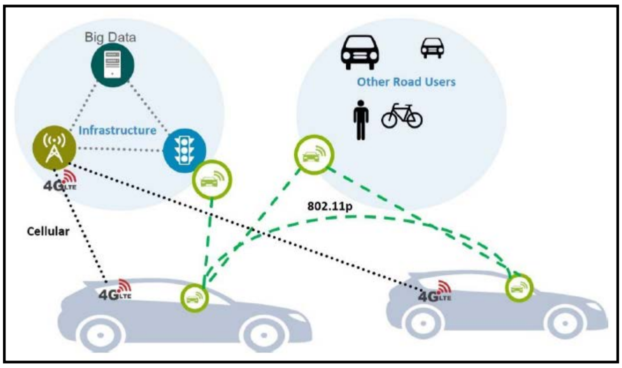

Fig.2 IEEE 802.11p vs. cellular connectivity pipes to the car (source [22])

A more detailed description of the features and applications of the above-mentioned communication systems can be found in [24]-[28].

The European Commission set in 2019 the start time of the actual deployment of mature C-ITS services and identifies in the C-ITS Platform Phase II Report [29], the list of services to be considered as overriding, given their high safety potential. In particular, on the basis of the priority required for their deployment services have been classified as Day 1 and Day 1.5. However, the Report specifies that such a list should not be seen as the 'official C-ITS service list', but only as a first benchmark for making interoperable the different deployment activities across the Union.
According to the analysed literature contributions, Table 1 shows a C-ITS services classification with reference to:

- involved interlocutors (i.e. V2V and V2I);
- kind of implemented standardised messages (i.e. CAM, DENM, SPaT and MAP);
- adopted communication technology (i.e. ETSI G5 and cellular);
- priority in deployment (i.e. Day 1 and Day 1.5).

3 European consortia

Within the European action to promote C-ITS services, a particularly relevant event is the Memorandum of Understanding (MoU) signed in June 2017 between C-Roads Platform and the Car 2 Car Communication Consortium (C2C-CC) [30] for enabling a close cooperation between the automotive industry, road authorities and road operators in view of the deployment of initial C-ITS services across the Union by 2019. C2C-CC was founded in 2002 by vehicle manufacturers affiliated and, today, comprises 88 members among automotive industry operators, equipment suppliers and research organisations. It played an important role in establishing European standards for V2V/V2I short-range communication and for the allocation of the 5.9 GHz band for such purposes (occurred in 2008), which has led to the standard ETSI G5.
As shown in [31] and [32], C2C-CC sets up a development roadmap which articulates the evolution of the standardisation and implementation of C-ITS services in five phases, as depicted in Fig.3. Moreover, the roadmap appropriately presents the evolution of the process as affected by automotive industry attitude in the development of C-ITS technologies on new vehicles to be put on sale, i.e. market penetration of equipped C-ITS vehicles.

C-ITS services	Involved interlocutors		Standardised messages				Communication technology		Priority in deployment	
	V2I	V2V	CAM	DENM	SPaT	MAP	ETSI-G5	Cellular	Day 1	Day 1.5
EBL		x		x			x		x	
EVA		x	x	x			x		x	
SSV		x	x	x			x		x	
TJW		x		x			x		x	
HLN	x	x		x		x	x		x	
RWW	x		x	x		x	x	x	x	
WTC	x	x	x	x			x	x	x	
VSGN	x		x		x	x	x	x	x	
VSPD	x		x		x	x	x	x	x	
PVD	x		x		x		x	x	x	
SWD	x		x				x	x	x	
GLOSA/TTG	x		x	x	x	x	x		x	
SigV	x		x	x	x	x	x		x	
TSP	x			x	x	x	x		x	
Infotainment[1]	x		x				x	x		x
LZM	x		x				x	x		x
ZAC	x		x				x	x		x
VRU	x	x		x	x		x			x
CCRW		x		x			x			x
MCA		x		x			x			x
WWD	x			x		x	x			x
CCN	x	x	x	x	x	x	x	x		x

[1]within infotainment tasks, the Traffic Information and Smart Routing (SmartR) service can involve also V2V communication.

Table 1 Classification of C-ITS services

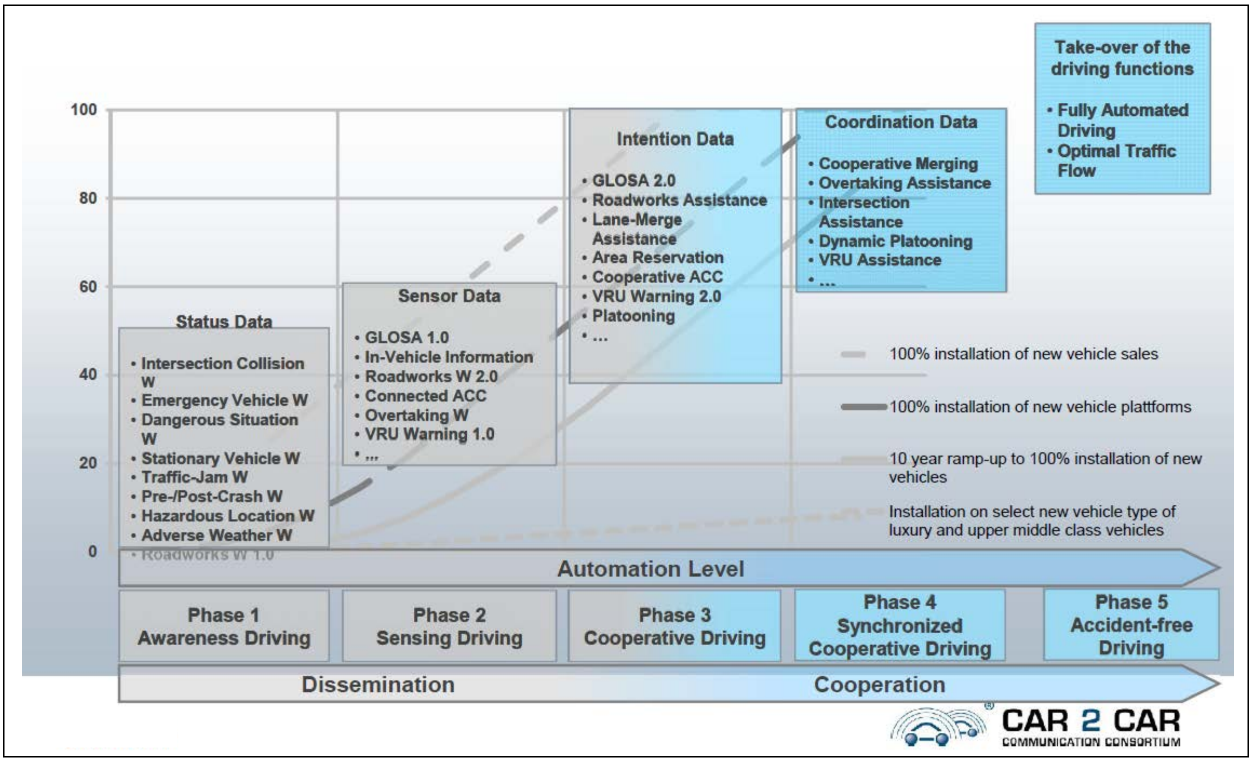

Fig.3 The C2C-CC applications roadmap (source [31])

Specifically, each phase is presented as an evolution of the previous one, in terms of the amount of data to be exchanged and, therefore, in terms of C-ITS functions allowed. In the first phase, vehicles are able to disseminate their status data, so as making other vehicles aware of their presence. In the second phase, sensor data (e.g. cameras and radar) can be disseminated in addition to status information, thus allowing vehicles not only to perceive other vehicles, but also to have a more accurate picture on what surrounds them. In the third phase, a further step forward is considered since vehicles can disseminate also their intention data. This is the first stage towards vehicle prediction capabilities and automation. Indeed, by predicting manoeuvres of other traffic users, vehicles can take their own decisions about how to respond to the traffic conditions and what behaviour adopt. Finally, phases 4, preceding the full automated driving (phase 5), foresees a synchronised behaviour for vehicles which are able to identify and follow optimal driving patterns.
C2C-CC, in turn, is part of the Amsterdam Group (AG) [33], a strategic alliance, born in 2011, with the aim of properly supporting a close cooperation among the involved stakeholders. Specifically, beyond C2C-CC, AG comprises other three umbrella organisations: CEDR (European organisation for national road administrations), ASECAP (European association of toll road operators) and POLIS (European cities and regions network). As shown in [34], AG action is focused on providing strategic support to European deployment projects and collaborating with standardisation groups, such as ETSI and the European Committee for Standardisation (CEN) [35].
Similarly to C2C-CC, in 2013, AG sets up a roadmap outlining a four-stage process for the full implementation of C-ITS services in Europe (see Fig.4).

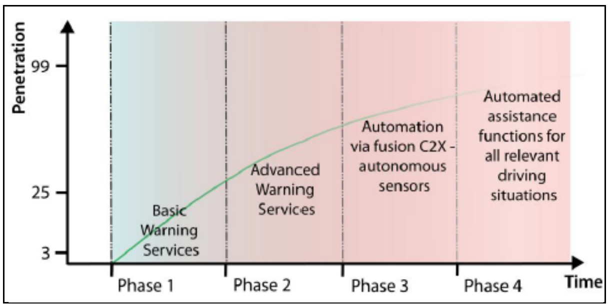

Fig.4 The AG roadmap (source [34])

4 Overview of the funded research projects

There are plenty of projects which have been set up with the mission of supporting the implementation of C-ITS services. Indeed, since the second half of the 2000's, such an issue has been given careful thought from the European Commission. Unfortunately, often, lines between EU projects and single Member State's initiatives, or eventually among EU projects themselves, are vague (e.g. some projects are nested in a larger EU plan). Notwithstanding the above, in the following, an overview of the noteworthy officially recognised EU C-ITS deployment projects currently in place is provided.
In June 2013, the National Transport Ministries of Germany, the Netherlands and Austria signed a MoU which marked the start of the *Cooperative ITS Corridor* project. As shown by [36], in the MoU Ministries agreed:

- to develop a common launch/rollout timetable for the implementation of the first cooperative applications on highways;
- to define common conventions that ensure a harmonized interface with vehicles in the three countries;
- to implement roadside facilities for the first collaborative applications.

The route identified as pilot site is shown in Fig.5 and is represented by the European corridor extending across the highways from Rotterdam (Netherlands), via Frankfurt/Main (Germany) to Vienna (Austria). In particular, the project was focused on RWW and PVD services; while, the communication technologies tested are based on a hybrid approach, combining ETSI G5 and cellular technologies. Such an approach, as shown in [38], ensures that the information is available on-site in real-time, in particular to increase road safety, but at the same time, with minimum delay/ latency, also on the road operator cloud for traffic information via cloud services. Currently, the work on the development of technical roadside components has reached the final stages and the deployment of vehicles is scheduled for 2019. Therefore, the following steps will be focused on the discussion with system operators from the automotive side, in order to reach agreements and specifications regarding organisational issues and interfaces. Further test phases are planned for additional services. Specifically, the aim is extending the scope of local hazard warnings, thus covering other use cases beyond road works, and investigating the in-vehicle signage tasks.

In contrast with Dutch and German contributions, the Austrian side of such joint initiative is outlined in a formally recognised project, that is *ECo-AT* (European Corridor – Austrian Testbed for cooperative systems). An extensive description of Cooperative ITS Corridor project and related initiatives, as well as involved partners, can be found in [37].

Fig.5 Cooperative ITS Corridor: Rotterdam – Frankfurt/M. – Vienna (source [37])

Another noteworthy project is *SCOOP@F* [39], a large-scale French initiative which involves 3000 test vehicles and 5 pilot sites across the country, namely Île-de-France, Corridor Est, Ouest, Bordeaux, Isère, amounting to 2000 km of roads (see Fig.6).

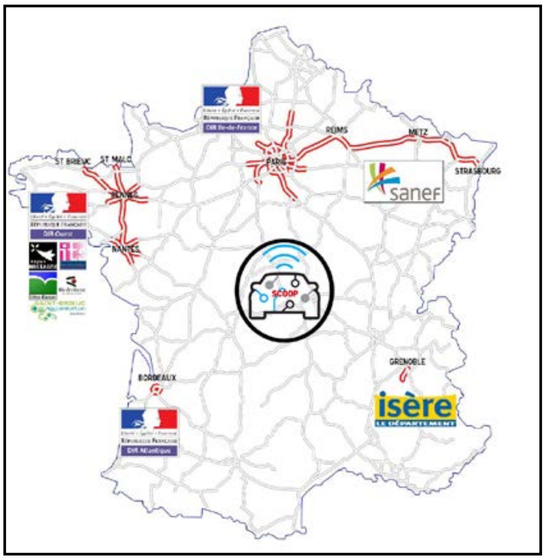

Fig.6 SCOOP@F pilot sites (source [40])

However, also cross tests with Austria, Spain and Portugal are planned. The project consists of two phases. The first step is focused on alert services, such as road works warning, information about current interventions of road maintenance agents and on-board signalling of hazardous and dangerous events (end of queue, slippery road, animal on the road, accident, etc.); while, the tested technology is based on the ETSI G5 standard. Currently, this part of the project is into the rolling phase, in which SCOOP vehicles will interact amongst themselves and with the 5 pilot site's equipped infrastructures. However, the testing phase is ongoing with regard to additional services, such as PVD and infotainment task, as well as the possibility of integrating cellular communications with ETSI G5 technology.

In the stream of harmonisation, it is worth mentioning the *InterCor* (Interoperable Corridors) project [41], aimed at coordinating C-ITS corridor initiatives of The Netherlands (within The Netherlands-Germany-Austria corridor) and France, as well as the United Kingdom and Belgian C-ITS deployment activities. Fig.7 shows European corridors involved in the InterCor project.

Fig.7 InterCor corridors (source [23])

In particular, the UK C-ITS deployment activities are referred to as *A2/M2 Connected Vehicle Corridor* (A2/M2 CVC) program [42] which has been established by the Department for Transport in partnership with Highways England, Transport for London and Kent County Council. The goal of the InterCor project is to extend national initiatives so as to increase services territorial coverage and reaching a high level of interoperability by means of cross-border tests. This requires a specific focus on security across the border and standardisation of the different deployment activities. Besides the already cited RWW, VSGN and PVD services, within InterCor, also GLOSA and new services in the field of freight and logistics are being tested (such as Freight Lorry Parking – FLP and Freight Slot

Availability – FSA). As regards to communication technologies, both short range and cellular networks, individually or in a view of being used within a hybrid approach, are under research.
Also Nordic countries (i.e. Denmark, Norway, Finland and Sweden) have their common deployment framework which is outlined in the *NordicWay* project. To be specific, currently, it is at its second wave of funding and is known as *NordicWay2* [43]. The first step was dedicated to a research phase; later, at the end of 2017, the first pilot sites, indicated in Fig.8 as red lines, were established.

Fig.8 NordicWay pilot sites (source [44])

C-ITS services	Denmark	Norway	Finland	Sweden
EBL		✓		✓
EVA			✓	✓
SSV	✓	✓	✓	
RWW	✓	✓	✓	✓
WTC	✓	✓	✓	
Other hazards	✓		✓	✓
VSGN		✓	✓	✓
VSPD		✓	✓	
PVD		✓	✓	
GLOSA/TTG		✓	✓	✓
SigV		✓	✓	
TSP			✓	✓

Table 2 C-ITS services tested within the NordicWay project (source [44])

Tested technologies are both short-range (ETSI G5) and medium/long-range (4G/LTE) communications; while, investigated services are the kind of Day 1. Further particulars are listed in Table 2, with specific reference to each involved country. Clearly, in this case, the challenge is to reach a suitable high safety-performance in snowy and arctic conditions; however, no official results on such deployment activities are currently available. Finally, it is worth noting that, within Norwegian C-ITS activities, also services in the field of freight are being tested.
Leaving aside European projects already closed and no longer funded (as, for instance, Compass4D, AdaptIVe, AutoNET2030), the above-mentioned programs are the most significant and promising initiatives currently ongoing. Indeed, not surprisingly, the most of them have been renewed for a second wave of deployment activities. For the sake of completeness, it is worth mentioning the pilot sites established across the Union within the C-Roads deployment program, which is detailed in [23]. However, an exhaustive list of relevant European projects across the Union, since 2005, can be found in [45].

4 Concluding remarks

The presented overview provides an insight on the current research activities in the European Union within the C-ITS and V2X communication fields. The aim is to outline the state of play in view of the milestone of 2019 which has been identified as the start time for the actual deployment of mature services.
Against a total budget of around EUR 300 million from the EU's framework programme for research and innovation 'Horizon 2020', within the period 2014-2020, the current picture presents the following highlights. The most adopted communication technology is definitively the short-range communication, according to the ETSI G5 standard. Also cellular technologies are being testing; however, the presence of the network, which affects transmission directness, makes them unreliable for safety-related C-ITS tasks. Nevertheless, the main goal of C-ITS service is exactly to improve road safety and, therefore, cellular technology results unsuitable for being implemented as the unique communication channel. For this reason, LTE/5G are being tested mostly in combination with ETSI G5 technology (i.e. hybrid approach). As regards to C-ITS services, the most mature tools are related to Hazardous Locations Notification (especially Road Works Warning), in-Vehicle Signage and Probe Vehicle Data

applications. Additionally, testing initiatives about GLOSA and Weather Conditions services seem to be well advanced.
Three different points can be identified as possible reasons for motivating a different state of play among the above-mentioned C-ITS services. Firstly, technological issues could delay the deployment of some tasks. In this regards, it can be stated that, currently, the use of cameras, radar transmitters, sensors, laser scanners and digital maps appears consolidated. Moreover, several Advanced Driver-Assistance Systems (ADAS), such as adaptive cruise control, emergency braking, backup cameras, and self-parking systems, have already been installed on commercial vehicles. However, in order to take the step up, thus enabling more complex tasks, as shown by [46], a systematisation and harmonisation of issues related to perception, localisation and human decision making process, in a fail-safe scenario, are required. Perception issues are related to the development of suitable algorithms able to read the surrounding environment with a high degree of reliability, by distinguishing, for instance, a stationary motorcycle from a bicyclist riding on the side of the street. Essentially, the object analysis is made complex by the several involved randomnesses (e.g. movement, background, weather conditions), which represent the reason of the failing of the most test activities and, sometimes, also the cause of fatal crashes. Regarding the localisation matter, it is related to the error range of the GPS signal. In this regard, EU undertook to further develop Galileo services and their accuracy for driverless mobility. Finally, the human decision making process should be suitably modelled in a software environment, thus reproducing users' choice behaviour. This is definitely the most complex aspect to be addressed and leads us to the second possible reason of a lack of development in certain C-ITS services, which is represented by a methodological issue (i.e. the lack of a robust procedure for successfully finalising the task). This happens, for instance, in the case of infotainment tasks. Indeed, although the technology for acquiring and delivering information is mature, the extremely dynamic nature of such a task makes services concerning, for instance, traffic information and smart routing not yet consolidated. In fact, users, after receiving certain information, change their behaviour, thus altering the utility and reliability of the same information for the rest of the drivers. Such a complication is missing, instead, when stationary objects are involved as, for instance, in the case of the road works warning. Therefore, as shown by [47], research questions still under debate are: How do drivers change their behaviour because of warnings/information given by the C-ITS services? Is safety affected by changes in driver behaviour due to C-ITS services?
Additionally, problems related to the spread of equipped C-ITS systems, as well as the standardisation of information and procedures, can be identified in the case of services involving a large number of vehicles or different traffic participants, such as shockwave damping, vulnerable road user protection and connected and cooperative navigation.
As already mentioned, EC looks forward to and will encourage a deployment of mature C-ITS services in 2019 and beyond; however, besides technological and functional aspects here addressed, several outstanding issues still remain, such as the timing of installation of C-ITS equipped vehicle sales by car-makers, the feedback of common users in purchasing them and legal matters on the liability of the parties.
Finally, it is worth noting that the resulting picture, however comprehensive, is not totally exhaustive since experimental activities and testbeds developed by the academic community and national research bodies are not described. Moreover, the current state of play is captured and, therefore, the provided discussion is lacking in the description of projects still in their infancy, whose activity schedule and outcome have not yet been disclosed. Instances of these projects are: ENSEMBLE [48], related to track platooning services; MAVEN [49], related to intersection safety; 5GCar [50], related to the fifth-generation cellular communication; AUTOPILOT [51], related to IoT V2X applications. Hence, beside an updating on such a kind of initiatives, the following research prospects are proposed: i) outlining particularly relevant national research projects which, although not promoted or disclosed (since they are not included in a European program), could turn out to be newsworthy; ii) analysing public-private partnerships aimed at establishing real-dimension pilot sites; iii) investigating the penetration rate of such technologies within the European market.

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