Course Syllabus

Topic Study 4: Communication technologies for ITS and C-ITS including relevant standards

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This course syllabus is part of the CAPITAL e-learning platform, a project funded by the European Union to design and deliver a collaborative capacity-building programme, including training and further education, for public and private sector practitioners in the field of (cooperative) intelligent transport systems (C-ITS & ITS).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 724106.

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This document was last updated on June 5th, 2018.
## Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>CAM</td>
<td>Cooperative Awareness Message</td>
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<td>C-ITS</td>
<td>Cooperative intelligent transport system</td>
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<td>CP</td>
<td>Certificate Policy</td>
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<td>C2C-CC</td>
<td>CAR 2 CAR Communication Consortium</td>
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<tr>
<td>DCC</td>
<td>Decentralized Congestion Control</td>
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<td>DENM</td>
<td>Decentralized Environmental Notification Message</td>
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<td>DSRC</td>
<td>Dedicated Short-Range Communication</td>
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<td>EC</td>
<td>European Commission</td>
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<td>ECTL</td>
<td>European Certificate Trust List</td>
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<td>ESoP</td>
<td>European Statement of Principles on HMI</td>
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<tr>
<td>FCD</td>
<td>Floating car data</td>
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<td>GA</td>
<td>Grant Agreement</td>
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<td>GLOSA</td>
<td>Green light optimal speed advisory</td>
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<td>GN</td>
<td>GeoNetworking</td>
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<td>HMI</td>
<td>Human-Machine Interaction</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>ITS</td>
<td>Intelligent transport system</td>
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<tr>
<td>ITS-G5</td>
<td>ITS-G5 is a European standard for ad-hoc short-range communication on 5.9 GHz frequency band</td>
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<td>IVI</td>
<td>In-Vehicle Information</td>
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<td>LDM</td>
<td>Local Dynamic Map</td>
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<td>LIDAR</td>
<td>Light Detection and Ranging</td>
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<td>LTE</td>
<td>4G mobile communications standard</td>
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<td>MAPEM</td>
<td>MAP (topology) Extended Message</td>
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<tr>
<td>MSD</td>
<td>Minimum Set of Data</td>
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<td>OFDM</td>
<td>Orthogonal Frequency-Division Multiplexing</td>
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<td>PKI</td>
<td>Public Key Infrastructure</td>
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<td>PO</td>
<td>Project officer</td>
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<td>PSAP</td>
<td>Public Safety Answering Point</td>
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<td>RDS</td>
<td>Radio Data System</td>
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<td>RHS</td>
<td>Road Hazard Signaling</td>
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<td>RTTI</td>
<td>Real-time traffic information</td>
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<td>SDO</td>
<td>Standards Development Organization</td>
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<td>SPATEM</td>
<td>Signal Phase And Timing Extended Message</td>
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<td>TLM</td>
<td>Trust List Manager</td>
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<td>TMC</td>
<td>Traffic Message Channel</td>
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<td>VDS</td>
<td>Variable Direction Sign</td>
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<td>VMS</td>
<td>Variable message sign</td>
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<td>VTP</td>
<td>Variable Text Panels</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<td>--------------------------------------------------</td>
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<td>V2X</td>
<td>Vehicle-to-Everything communication</td>
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<td>WAVE</td>
<td>Wireless Access in Vehicular Environments</td>
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<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<td>WP</td>
<td>Work Package</td>
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1. Introduction

Intelligent Transport Systems (ITS) has many definitions. According to the European Commission: “Intelligent Transport Systems or ‘ITS’ means systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport”. (European Commission 2010)

Communication has always been a key feature of ITS and the role of communication between various road users and systems increase when we move to the Cooperative systems. Cooperative Intelligent Transport Systems (C-ITS) use technologies that allow road vehicles to communicate with other vehicles, with roadside infrastructure including traffic signals as well as with other road users. The systems are also known as vehicle-to-vehicle communications, or vehicle-to-infrastructure communications, or vehicle-to-everything (V2X), which covers all previously mentioned. (European Commission 2016, p. 8)

ITS is already on the market and it has been utilized for many years to support European transport policy - safer, cleaner and more efficient transport. During the recent years the standards of the first C-ITS services have been completed. C-ITS functionality has been already tested in various research projects and it is currently being piloted e.g. in European corridor projects. The commercial deployment of C-ITS in Europe is starting soon and the final open issues have been discussed in the framework of C-ITS Platform supported by the European Commission. Due to large number and variability of ITS systems available, this topic study provides a limited number of ITS and C-ITS services as an example while focusing more on architectures, communication technologies and standards behind the applications and services.

Standard is described by (CEN no date (n.d.)) in following way: “A standard is a document that sets out requirements for a specific item, material, component, system or service, or describes in detail a particular method or procedure. Standards are established by consensus and approved by recognized standardization bodies… Standards provide individuals, businesses and all kinds of organizations with a common basis for mutual understanding. They are especially useful for communication, measurement, commerce and manufacturing… Standards are voluntary, which means that businesses and other organizations are not legally obliged to apply them. However, in certain cases standards may facilitate compliance with legal requirements, such as those contained in European directives and regulations.”

2. Objectives

The objective of this topic study is to provide a timely, comprehensive and consistent overview of 1) communication technologies for ITS and especially for C-ITS and it also includes 2) general information about standardisation and for C-ITS standards on the
European level. The topic study aims to provide background information for development of CAPITAL study module “Communication technologies for ITS and C-ITS including relevant standards”.

Chapter 3 describes a few examples of ITS services and applications and short overview of the FRAME architecture. This topic study focuses more on the C-ITS architecture, communication and standards that is described in Chapter 4. The Chapter 5 provides information about the standardisation for ITS and C-ITS and finally the Chapter 6 includes a short overview on testing and interoperability.

3. Intelligent Transport Systems

3.1. ITS Applications (Technologies)

There are numerous ITS applications on the market and there are variations in their implementations and use between different countries. The iMobility effects database has been compiled by iCarSupport in order to maintain the state-of-the-art knowledge of the effects of different ITS, intelligent vehicle and infrastructure systems. This list provides a good overview of several ITS applications. A list of the ITS application examples, which includes communication element, is presented below. The stand-alone (in-vehicle) applications are not included. Another list of ITS applications from the road operator/authority point-of-view can be found from the EU EIP project Deployment Guidelines. EU EIP project supports European road operators and authorities in the deployment of harmonised ITS services. The list of these ITS applications is also included in this chapter.

3.1.1. Dynamic Traffic Management

The iMobility Effects Database (n.d.) provides the following description: “Dynamic traffic management systems and local danger warnings are used to increase the safety and flow of traffic in cases of disturbance caused by incidents, congestion and adverse weather. Dynamic traffic management systems may also be used to implement hard shoulder running to increase road capacity locally during peak hours. The systems are operated automatically, semi-automatically or manually from traffic control centres based on fixed monitoring systems or mobile sensors (FCD etc.) on location. The systems employ Variable Message Signs or VMS to give the information to the drivers. Three categories of VMS exist based on the types of messages given: 'regulatory messages', 'danger warning messages' and 'informative messages'. The dynamic traffic management systems usually use regulatory messages, sometimes accompanied by danger warning and informative messages.”

As retrieved from http://www.imobility-effects-database.org/applications_11.html
3.1.2. Local Danger Warnings

The iMobility Effects Database (n.d.) provides the following description: “Dynamic traffic management systems and local danger warnings are used to increase the safety and flow of traffic in cases of disturbance caused by incidents, congestion and adverse weather. The systems are operated automatically, semi-automatically or manually from traffic control centres based on fixed monitoring systems or mobile sensors (FCD etc.) on location. The systems employ Variable Message Signs or VMS to give the information to the drivers. Three categories of VMS exist based on the types of messages given: ‘regulatory messages’, ‘danger warning messages’ and ‘informative messages’. Local warning systems use danger warning messages.”

As retrieved from http://www.imobility-effects-database.org/applications_12.html

3.1.3. Dynamic Navigation Systems

The iMobility Effects Database (n.d.) provides the following description: “Dynamic navigation utilizes current traffic event and transport network status data for adjusting the routing process in electronic navigation systems. This enables users to avoid routes with accidents, roadworks, road closure, and congestion in “real time”. The Traffic Message Channel (TMC) is mostly used to provide the basic traffic event information countries in Europe using RDS radio communications. More enhanced and individually sourced content is used to improve the standard TMC services in terms of accuracy and quality. These kinds of services are being provided via cellular networks.”

As retrieved from http://www.imobility-effects-database.org/applications_17.html

3.1.4. Real-Time Traffic Information

The iMobility Effects Database (n.d.) provides the following description: “Real-time Traffic and Travel Information” includes all information which is relevant to organize and to optimize traffic flow and which can give advice to the mobile user, usually the driver, and to contribute to road safety and efficiency. The eSafety goal is to provide the majority of drivers with actual intra-urban traffic information and to get adequate urban traffic information in 50% of all major metropolitan areas in the EU. RTTI contains:

- the collection of relevant traffic data,
- the interpretation of that information and prepare it for further use and distribution,
- the application of that information to operate infrastructural installations such as traffic lights or moving traffic signals,
- the wireless transmission of the RTTI to the mobile user by public or private broadcast and/or two-way systems such as cellular networks, WLAN, Satellite transmission.”

As retrieved from http://www.imobility-effects-database.org/applications_10.html
3.1.5. Extended Environmental Information (Extended FCD)

The iMobility Effects Database (n.d.) provides the following description: “The idea of Floating Car Data (FCD) is to monitor individual vehicles to gather data concerning the traffic situation on the whole road network. The in-vehicle equipment records the location of the car, speed and possibly other information such as acceleration or deceleration, and sends the recorded information to the central system or to other cars. The central collected data can be used as content for different applications and services.”

As retrieved from http://www.imobility-effects-database.org/applications_09.html

3.1.6. eCall

The iMobility Effects Database (n.d.) provides the following description: “The 112 eCall automatically dials Europe's single emergency number 112 in the event of a serious road accident and communicates the vehicle's location to the emergency services. eCall is activated automatically as soon as in-vehicle sensors and/or processors (e.g. airbag) detect a serious crash. Once set off, the system dials the European emergency number 112, establishes a telephone link to the appropriate emergency call centre (aka Public Safety Answering Points – PSAPs) and sends details of the accident (aka Minimum Set of Data – MSD) to the rescue services, including the time of incident, the accurate position of the crashed vehicle and the direction of travel. An eCall can also be triggered manually by pushing a button in the car, for example by a witness to a serious accident.”

As retrieved from https://ec.europa.eu/transport/themes/its/road/action_plan/ecall_en

The European Parliament adopted the legislation on eCall type approval requirements and made it mandatory for all new models of M1 and N1 vehicles to be equipped with eCall technology from 31 March 2018 onward. The Public Safety Answering Points (PSAP) need to be equipped with eCall from 1 October 2017.

3.1.7. Forecast and Real Time Event Information

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description:

“Forecast and Real Time Event Information Services” are defined as the provision of information about both expected and unexpected events to road users on identified road segments of the TEN-T network and interfaces. This predictive or real-time information could be provided on-trip and pre-trip using different information channels, accessible by the road user via different end-user devices. The service may comprise common information as well as individual (personalised, on-demand) information. “Events” are defined as – expected or unexpected – abnormal situations which may lead to adverse effects on the road regarding traffic safety, efficiency and environmental effects.”

“Forecast and real-time event information services are currently well developed and widespread across Europe. Many European road operators/service providers use websites
as a means of information provision, which can assist with journey and route planning. Road network information combined with both historic and real time passenger information enables road users to make informed choices between private and public transport options and help impact on the mode choice of travel. On-trip information using Variable Messages Signs (VMS) exists extensively across much of Europe. Traffic information (spoken word), used pre-trip as well as on-trip, is available on several radio stations throughout Europe. RDS-TMC (Radio Data System Traffic Message Channel) has been deployed in most European countries and deployment is underway in several Central and Eastern European countries.”

“The use of in-vehicle navigation systems with traffic information is also widespread. These systems tend to have a data connection which offers them the possibility to connect with a service provider. There is also exponential growth in the market for smartphones and software applications which can act as in-vehicle navigation system.”

**3.1.8. Traffic Condition and Travel Time Information Service**

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “‘Traffic condition and travel time information service” means, both pre-trip and on-trip, the provision of traffic condition (Level of Service) and travel time information on identified road segments of the TEN-T network and interfaces, thus enabling road users to optimize and better anticipate their journey ahead. This predictive or real-time information will use different information channels, accessible by the road user via different end-user devices. The service may comprise common as well as individual (personalised, on-demand) information.”

“There are various European services in operation which can be distinguished according to the information providers, i.e. public road authorities, private road operators, broadcaster and other private service providers. Different information channels could be used for the provision of the service to the road user as there are roadside information infrastructure, Internet, broadcasting facilities used by media, data communication, mobile radio or infrastructure to vehicle facilities.”

**3.1.9. Speed Limit Information**

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “The function of a speed limit information service is to provide road users with credible travel information about the prevailing speed limits that applies on the roads that they are travelling on.”

“Delivery platforms for the speed limit information service will range from traditional media such as roadside signs to innovative media such as VMS, in vehicle navigation systems, digital maps and smart phone applications.”
3.1.10. Weather Information Service

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description:
“The main objective of providing weather information to the driver is improving the traffic safety and the efficiency of the European road transportation system. If the driver is informed on the upcoming weather situation he is able to adapt his driving behaviour. Weather information can be included into both pre- and on-trip journey planning. This may reduce congestion and the number of fatalities and accidents. The vision is that a user provided with high quality information will react and adapt his travelling and driving behaviour including a change of routes, modes or trip schedule (time of departure) as well as changes in the way of driving.”

3.1.11. Co-Modal Traveller Information Services

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Co-modal traveller information services offer in parallel comparative information of different modes / means of transport (multi-modal) and / or the combination of different modes / means of transport within the same route (inter-modal). The services offer information for at least public transport, car transport and usually pedestrian and bicycle transport. Co-modal traveller information services can foster a modal shift towards reputed more environmental friendly modes / means of transport and lead to a more efficient network operation as well as a better utilization of the transport infrastructure.”

3.1.12. Dynamic Lane Management

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “The fundamental concept behind Dynamic lane management (DLM) is to provide a service that enables a temporally modifiable allocation of lanes by means of traffic guidance panels, permanent light signals, multiple-faced signs, LED road markers and closing and directing installations.

Applications of this service are related to tidal flow systems, lane allocation at intersections, lane allocation at tunnels and hard shoulder running.

The overall objective of the dynamic lane management (DLM) service is to allocate traffic flows and therefore obtaining a higher capacity through better usage of the available cross-section and also to achieve a temporary closing of lanes in case of accidents, incidents, maintenance work and construction measures (safeguarding of lanes).”

3.1.13. Variable Speed limits

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “The main purpose of VSL is to help drivers to travel at an appropriate speed considering the
prevailing traffic or weather conditions. Sensitive road segments, like tunnels, are often subject to VSL deployment for safety reasons. VSL can also be used to mitigate negative effects for society in general, like pollution or noise and to increase throughput. The use of VSL for environmental purposes is small today, but an increase is expected.

3.1.14. Ramp Metering

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Ramp metering (RM) is implemented via the installation of traffic signals on the on-ramps which regulate the flow of traffic joining the motorway during peak or congested periods. It does this by controlling the discharge of vehicles from the on-ramp, holding vehicles back and breaking up on-ramp platoons, thus reducing the interference of merging vehicles and helping maintain the flow of traffic on the main carriageway. The traffic signals are generally operated in dependence of the currently prevailing traffic conditions on both the main carriageway and the on-ramps.”

3.1.15. Hard Shoulder Running

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Hard Shoulder Running enables the dynamic temporary use of hard shoulders at road sections, including junctions with the aim to increase road capacity when necessary. Hard Shoulder Running could be considered similar to the creation of an extra lane, but with specific safety issues due to the fact that it is still a hard shoulder where users can stop if they break down. Hard Shoulder Running is triggered by traffic demand, at fixed times or due to manual requests and applied to bottlenecks, locations with poor safety records (black spots) with a recurrent - but not constant - lack of capacity.”

3.1.16. HGV Overtaking Ban

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Service Description – An HGV Overtaking ban service means to channel the heavy goods vehicles onto a single lane (slow lane). The heavy goods vehicles overtaking ban implementation is one of the traffic management measure allowing traffic managers and road operators to propose solution for a better fluidity of their network during peak periods. This traffic control measure constitutes one of the priority services to improve the cohabitation of heavy goods vehicles and private cars on networks with high levels of traffic.”

3.1.17. Intelligent and Secure Truck Parking

The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “The objective of parking area operators is to make the optimum use of the existing truck parking capacities along the highways and to improve safety and security on their (truck) parking area. “Intelligent Truck Parking” will contribute towards optimising the use of available parking areas, which are a limited resource in many corridors today.”
“Pre-trip travel planning has developed towards dynamic smartphone applications and easy-to-access websites with TPA as Point of interest, or to information platforms. A few European road operators employ websites as a means of information provision, which can assist with route planning.”

“There is also an exponentially growing market for smartphones which can act as in-vehicle navigation systems and/or provide parking information through parking apps on smartphones.”

3.2. Communication Technologies for ITS

The previous chapter listed a number of ITS applications that have been implemented with various communication technologies. Here is a short list of communication technologies (except C-ITS communication technologies, which are covered later in the document).

The EIP+ project C-ITS White paper (EIP+ 2016) includes a comprehensive list of various communication technologies, which are used in ITS sector, and their characteristics:

3.2.1. Fixed Networks

The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview:
“Fixed communication networks carry the majority of communications traffic worldwide and were used for the earliest telephone circuits, they cover a wide range of bandwidths from single telephone lines to 100s of Tbit/s.”

In ITS fixed networks are utilized between the backend systems, between control centres and fixed outstation equipment (like fixed monitoring systems or message signs, etc.) and mobile communication infrastructure nodes.

3.2.2. Broadcast Radio

The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview:
“FM broadcast has been in use for many years and is readily available in most vehicles via a built radio receiver, it is one of the main mediums for distributed traffic information. The area coverage is close to 100%. Many local and regional radio stations broadcast traffic reports at peak times throughout the day with car radio programs or music interrupted for the traffic alerts.”
3.2.3. RDS-TMC and DAB-TPEG

The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview:
“Traffic Message Channel is sent via the Radio Data System (RDS) embedded in some FM broadcasts. The system is based on geographical reference points (TMC locations) in combination with text and timestamps. Information about traffic accidents, road works and road weather is transmitted. To receive the messages the car radio, a GPS-navigator or Smartphone must support RDS-TMC.”

“In Europe (and throughout the world), the FM radio system is in the process of being replaced by DAB-radio (Digital Audio Broadcast). As with FM, Traffic Messages can be transmitted using DAB radio with the encoding being in accordance with Transport Protocol Expert Group (TPEG).”

3.2.4. Public Land Mobile Networks (cellular networks)

The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview: “2G GSM has coverage over most of the population and has been used in certain telematics applications. eCall was designed to use 2G communications, but will inevitably use later generations of cellular network with higher bandwidth.”

“3G WCDMA is the first generation of mobile broadband and has good coverage in populated areas. It has low latency and can be used to exchange messages between vehicles for many C-ITS use cases. However transmission from remote transmitters may be unreliable.”

“4G LTE is a much improved mobile broadband being deployed at the time of writing. The coverage of mobile broadband will expand rapidly as new spectrum (700 and 800 MHz) with good propagation characteristics is deployed and existing spectrum licenses become “technology neutral”.”

“5G is the next generation of mobile network technology. It is under definition now with expected deployment around 2020. The performance target is to make it “ten times better” than 4G in many categories including latency and reliability and it is designed to support all aspects of the ‘internet of things’.”

3.2.5. Satellite Communications

The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview: “Satellite communications systems can offer a huge benefit of wide coverage. Several operators have hence developed services that offer both voice and data services on regional or global basis, the following represent the type of satellite constellation with 100+ operators offering broadcast, broadband & mobile services and application. Enhancement in capacity and coverage at regional scale can be achieved by the launch of a single GEO satellite payload. Unlike terrestrial networks, satellite services are designed to cover and provide
reliable connectivity to large areas of land (rural and urban), sea and air."

### 3.3. FRAME architecture for ITS and C-ITS

The FRAME Architecture (FRAME Forum, 2017) is a top-down approach to plan the implementation and deployment of ITS and C-ITS architectures in an integrated and interoperable manner. It is a methodology in the early stage of system engineering process to collect the requirements for the new system systematically and follow up the collected requirements in various standard views as output, which together form the ITS architecture. These views, or single aspect representations of the architecture, can be functional, data, communication, security or organizational views of the system, depending on the extent to which stakeholders are involved in implementing a new system. The common methodology allows for different stakeholders, such as users, operators, and providers, to share a “common language” in expressing their requirements for the applications and services provided by the ITS architecture. It aims to formalise the desires and produces a structure for the architecture that does not impose technical or organisational assumptions on the final deployment in the first functional and data views. This way the final system structure and the original design concept do not need to change when the technology evolves.

ITS architectures can represent systems from local services to national level systems and they can cover anything from the technical aspects to legal issues. An ITS architecture should integrate to existing systems with appropriate interfaces and, at the same time, allow for future extensions and upgrades. It also has a set of expectations on its performance, maintainability, ease of use, and so on, all of which it has to satisfy.

Designing and implementing such a system in a networked transport environment is a complex task. The FRAME architecture was created to solve this task by offering a shared, common approach to capture the objectives and requirements of each actor and map them into specific, pre-defined, formalised components of the system.

The creation of an ITS Architecture with the FRAME Architecture starts with a conversation with the stakeholders to extract their Aspirations for the overall concept of the system. The Stakeholder Aspirations are high-level objectives and requirements of the whole ITS system and are received from everyone involved in the deployment of the ITS architecture. These Aspirations are then mapped onto the pre-determined User Needs provided by the FRAME Architecture, or, the Aspirations determine the sub-set from all available User Needs that will then lay the groundwork for the system structure for the ITS architecture. The User Needs describe what behaviour the system will provide in a clear and unambiguous way and connect to Functions, which describe exactly what is done to the data at that point in the system. The sub-set of User Needs extracts the ITS Architecture from the whole FRAME Architecture.

Each Low-level Function has a list of User Needs that are served by that Function and an
Overview of its functionality. It also has a list of input and output Data Flows and a detailed Functional Requirements, which describe exactly what the Function does with the data. They are intended to be simple and easily describable. High-level functions are just groups of Low-level Functions to mask a more complicated series of functions as one Function.

The FRAME Architecture also list different Data Stores that hold the data used by components of the system. They have detailed description of the data and connect to Functions that use that data.

Data Flows are the links between Functions, Terminators, and Data Stores. They specify how data is moved around in the ITS Architecture. Terminators are points of the system that connect to the real world (e.g. input data from a sensor or a driver of a vehicle).

These abstract concepts, and others not listed here, create the structure of the system, the ITS Architecture, in a technology independent way. This structure can then be viewed from different perspectives with views provided by the FRAME Architecture.

The Functional View will provide the functionality and processes needed, as a set of diagrams and specifications, to implement the ITS Architecture in a way that satisfies the User Needs. The Physical View will show, in a similar manner, where each component (for example, the Data Stores) are physically located in the deployment. The Communications View will describe the different types of communication channels between components of the system. The Organisational View described the ownership and business issues of the ITS Architecture, e.g. who owns or manages different parts of the structure and what are the contractual relationships between the parties involved.

Thus, the system structure produced by the FRAME Architecture will describe the components of the system and their connections, as well as their relationship with the outside world and, if needed by the specific system implemented, the organisational and business connections. If each component of the system, and their connections, are developed to match the descriptions and specifications provided in the system structure, the final deployment will satisfy the User Needs and, thus, satisfy the original Stakeholder Aspirations for the deployed ITS architecture.

Within the FRAME NEXT project a series of implementation architectures for the priority areas of the ITS Directive (2010/40/EU) will be implemented together with their organisational and physical views. These architectures will include ITS services such as eCall, C-ITS and truck parking. With these implementation examples from various countries, future users can start with predefined elements in their development of ITS Architectures. The elements adapt to the users’ needs and, at the same time, contribute to the interoperability of systems. In the best-case scenario, they could extend the interoperability to generated ITS services.
4. C-ITS

The European Commission has published the European strategy on C-ITS systems in 2016 (European Commission 2016a). The Commission has supported the development of C-ITS for more than a decade via substantial funding. C-ITS research activities have been complemented by large-scale field-operational and during the recent years by deployment projects on the European Trans-European Transport network.

In 2016 the C-Roads Platform was established as the platform of Member State authorities and road operators for harmonising the roadside C-ITS deployment across Europe. In addition, the C-Roads Platform is linking all ongoing C-ITS deployment activities, supported by the European Commission. Also the automotive industry has been active in C-ITS development especially via CAR 2 CAR Communication Consortium (C2C-CC), which is an industry driven organisation initiated by European vehicle manufacturers and supported by equipment suppliers, research organisations and other partners. As the number of infrastructure C-ITS deployment initiatives in Europe are growing, the CAR 2 CAR Communication Consortium in collaboration with the C-Roads Platform are together promoting the C-ITS deployment which should be starting in 2019. (C2C-CC 2017)

Starting from 2014 the European Commission introduced the C-ITS platform to identify barriers and find solutions for C-ITS deployment in Europe. The first phase of the C-ITS platform published the final report in January 2016 (European Commission 2016b). After the first phase of the C-ITS Platform, the Commission has identified issues, which need to be tackled at EU level to ensure coordinated deployment of C-ITS services in 2019. The second phase of the C-ITS Platform has published the final report in September 2017 including results from the Working Groups on Security, Data Protection, Compliance Assessment and Hybrid Communication and others (European Commission 2017c).

In Europe C-ITS deployment is based on voluntary market introduction. In USA, the Notice of Proposed Rulemaking (NPRM): 49 CFR Part 571 “Federal Motor Vehicle Safety Standards; V2V Communications” has published for comments in early 2017 (Federal Register 2017). Currently it is still open if V2V communication based on dedicated short-range radio communication (DSRC) will become mandatory in the USA. DSRC standards in the U.S. are similar to the Cooperative Intelligent Transport (C-ITS) standards in Europe.

4.1. C-ITS architecture

4.1.1. ETSI architecture

The architecture for the C-ITS is defined in ETSI standards. Intelligent Transport Systems (ITS); Communications Architecture (ETSI EN 302 665) provides the global communication architecture of communications for ITS. It specifies mandatory and optional elements and interfaces of ITS architecture (HIGHTS 2016). In addition some elements of ITS applications,
especially those directly related to the ITS architecture, are also considered in the overall high number of relevant standards in the C-ITS area. These documents are enabling different implementation architectures, based on two steps of work in the direction of common implementation of C-ITS on roadside infrastructure networks and in vehicles, these steps are (C-Roads 2017c):

- A selection of the group of standards necessary and the common definition of those elements which are mandatory in the standards, and
- The publication of the choices and decisions taken in the definitions for the Common implementations in a fully documented communication profile for the respective group of C-ITS Stations (e.g. Vehicle, or Roadside or personal ITS Station).

The communication architecture for ITS in EN 302 665 is derived from the OSI model (Open Systems Interconnection Reference Model). This is an open standard supporting GeoNetworking (GN) IP stack and multiple access technologies. Cooperative ITS systems

![Diagram of ITS station reference architecture](https://example.com/diagram.png)
The C-ITS messages of ITS-G5 use the GeoNetworking (GN) protocol. The GeoNetworking protocol supports:

- point to point
- point to multi point
- message dissemination with a defined hop count
- message dissemination within a defined geographic area

The following ITS sub-systems (including ITS station) are define in the ETSI EN 302 665:

- central ITS sub-system (central ITS-S); part of an ITS central system,
- vehicle ITS sub-system (vehicle ITS-S); in cars, trucks, etc., in motion or parked,
- roadside ITS sub-system (roadside ITS-S); on gantries, poles, road trailers,
- personal ITS sub-system (personal ITS-S); in hand-held devices,

These stations together including the stakeholders operating them form the C-ITS network and need to cooperate to be able to exchange traffic information seamlessly between them.

### 4.1.2. C-ITS messages

The Cooperative Awareness Message (CAM) has been described by ETSI (ETSI 2014a): “The several message services specified for C-ITS. The most important ones are the Cooperative Awareness Message (CAM) and the Decentralized Environmental Notification Message (DENM) services. The Cooperative Awareness Service enables the exchange of information between road users and roadside infrastructure, providing each other’s position, dynamics and attributes. Awareness of other road users is the basis for several road safety and traffic efficiency applications. This is achieved by regular exchange of information from vehicle to vehicle (V2V), and between vehicles and road side infrastructure (V2I) based on wireless networks. Typically, vehicle ITS station broadcasts the Cooperative Awareness Messages (CAM) at maximum rate of 10 Hz, providing real time high dynamic information of the vehicle, such as position, time, basic sensor data, vehicle type, size, etc. EN 302 637 specifies the syntax and semantics of the Cooperative Awareness Message and provides detailed specifications on the message handling.”

A document prepared by the Data Protection WG of the C-ITS Platform (C-ITS Platform 2017) provides a good overview of the CAM messages and how they are used: “C-ITS equipped vehicles communicate with their close environment via the short-range IEEE 802.11p protocol. The signal broadcast from the vehicle ranges between 300 and 500 meters depending on the circumstances. This technique has been chosen because of the low latency of short-range communication directly between the vehicles involved and to be less dependent from other means of information and communication. This low latency is necessary because safety related messages require very short reaction times. The short reaction time becomes even more relevant in higher levels of automation. Broadcast
messages will be received and understood in other vehicles or by roadside units.

CAM are standardised to be ‘single-hop’ messages. They can only be processed by vehicles in range and are not meant to be forwarded to other vehicles, since their relevance outside of their range would be limited and forwarding of CAM would create excessive volumes of data traffic. The CAM contains by default a heading, a timestamp, then basic data like vehicle pseudo ID and position. There is also a sub-set refreshed in high frequency mode (HF) that includes data like: speed, acceleration and curvature. Other vehicle status information are given in low frequency refreshing mode, like vehicle role or category and some basic sensors. There is also an optional container relating to vehicle category details (public transport, rescue). The aim of the CAMs is to inform other ITS Stations about current vehicle/C-ITS status and presence.”

The Decentralized Environmental Notification Message (DENM) has been described by ETSI (ETSI 2014a): “EN 302 637 defines the Decentralized Environmental Notification (DEN) Basic Service. The Decentralized Environmental Notification Message (DENM) contains information related to a road hazard or an abnormal traffic condition, including its type and position. Typically for an ITS application, a message is disseminated to ITS stations that are located within a geographic area through direct vehicle-to-vehicle or vehicle-to-
infrastructure communications, in order to alert road users of a detected and potentially dangerous event. The transmission of DENM may persist at a typical transmission rate of 10 Hz, as long as the detected event persists. At the receiving side, the message is processed and the application may present the information to the driver if it is assessed to be relevant.

A document prepared by the Data Protection WG of the C-ITS Platform (C-ITS Platform 2017) provides a good overview of the DENM messages and how they are used: “The DENM is event-based, it is sent, if a vehicle senses special conditions or incidents. It is meant for urgent emergency situations. The DENM is sent in addition to the CAM. It contains location information about the event (not the transmitting vehicle) and complements that data with a range of events or conditions (e.g.: different weather conditions, visibility, road adhesion or collision warnings). DENM are ‘multi-hop’ messages. They could be sent from an ITS Station to a certain area and get there ‘hopping’ from ITS station to ITS station. Similar to the CAM it also consists of data containers that are mainly filled with data defined in the Common Data Dictionary (specified in ETSI TR 102 894).”

![Figure 3. Structure of a DENM (ITS Platform 2017)](image)

Other important messages are In-Vehicle Information (IVI) message and messages for signalised intersections. ISO/TS 19321:2015 specifies the In-Vehicle Information (IVI) data structures that are required for exchanging information between ITS Stations for In-vehicle
presentation of external road and traffic related data (ISO/TS 17425) and Contextual speed (ISO/TS 17426). IVI messages transmit information, which has been verified by road operator, and are coherent with the information that is displayed on a road sign or VMS. Messages related to signalised intersections (defined in ETSI TS 103 301) are Signal Phase And Timing Extended Message (SPATEM) and Intersection topology extended message (MAPEM). These messages provide information on signalised intersections, enabling applications such as Green Light Optimized Speed Advisory (GLOSA). (Scholliers 2016)

A Roadside ITS-S provides roadside information to road users using ITS networks, such as road signage information, traffic light phase and timing information and road topology data. At the reception of the roadside information, vehicle ITS-S may process the information for application usage, for example informing driver of the road signage information (e.g. speed limit) or adjust the speed to pass the intersection (GLOSA).

4.1.3. C-ITS services

C-ITS service deployment has been boosted by the European Commission e.g. via C-ITS Platform activities. One of the conclusions of the C-ITS Platform final report in 2016 (European Commission 2016a) was a list of early deployment Day 1 and Day 1.5 C-ITS services. This list of Day 1 services includes technologically-mature C-ITS services should be deployed as soon as possible.

- Hazardous location notifications:
  - Road works warning
  - Slow or stationary vehicle(s) & traffic ahead warning
  - Weather conditions
  - Emergency brake light
  - Emergency vehicle approaching
  - Other hazards

- Signage applications:
  - In-vehicle signage
  - In-vehicle speed limits
  - Signal violation / intersection safety
  - Green light optimal speed advisory
  - Probe vehicle data
  - *Shockwave damping (falls under European Telecommunication Standards Institute (ETSI) category ‘local hazard warning’)

(* Shockwave Damping is a service that aims to smoothen traffic flow in dense traffic conditions by giving optimal speed recommendations which can be for example displayed in a vehicle to the driver)

In a second phase, the Day 1.5 C-ITS services list would be deployed:

- Information on fueling & charging stations for alternative fuel vehicles
• Vulnerable road user protection
• On street parking management & information
• Off street parking information
• Park & ride information
• Connected & cooperative navigation into and out of the city (first and last mile, parking, route advice, coordinated traffic lights)
• Traffic information & smart routing

The list of Day 1.5 C-ITS services includes services for which full specifications or standards might not be ready for large-scale deployment from 2019. Although, these service have been considered to be generally mature.

C-Roads Platform (C-Roads 2017c) provided detailed descriptions of the day-1 C-ITS services in the first release of the harmonised communication profile for Cooperative Intelligent Transport (C-ITS) services document in September 2017. Overview for every category of C-ITS Services from the document is presented below with example use cases.

Road Works Warning (RWW) Service
C-Roads Platform (C-Roads 2017c) service introduction and use cases: “The service is to provide warnings to road users about road works, which can be mobile or static. Possibly, when a dangerous vehicle approaches a road works, a warning can be sent to the driver of the dangerous vehicle and to workers.

Use Cases:
• Closure of part of a lane, whole lane or several lanes
• Alert planned closure of a road or a carriageway
• Alert planned road works – mobile (e.g. cutting the grass or renewing the lane markings)
• Alert operator vehicle approaching / in intervention / in patrol
• Winter maintenance (Salting, snow removal)
• Dangerous vehicle approaching a road works: warning to the dangerous vehicle
• Dangerous vehicle approaching a road works: warning to workers”

In Vehicle Signage (IVS) Service
C-Roads Platform (C-Roads 2017c) service introduction and use cases: “In Vehicle Signage is an information service to inform road users on actual, static or dynamic (virtual) road signs via in-car systems. The road signs can be mandatory or advisory.
Use Cases, several use cases where Variable Message Signs (VMS), Variable Text Panels (VTP) or Variable Direction Signs (VDS) is used):
• In-vehicle signage dynamic speed limit information
• In-vehicle signage embedded VMS
• In-vehicle signage other signage information
• Smart routing / route advice
• Travel time (of specific vehicles)”
**Other Hazardous Location Notification Service**

C-Roads Platform (C-Roads 2017c) service introduction and use cases: “This C-ITS service describes an I2V warning message related to a series of “possibly hazardous” events on the road, were the road users approaching it are informed and hereby warned about a hazardous location on their way.

Use Cases, The events (and therefore the scenarios of the C-ITS service) can be e.g. the following warnings:

- Accident zone
- Temporarily slippery road
- Animal or person on the road
- Obstacle on the road
- Vehicle stopped or broken down"

**TLM – Traffic Light Manoeuvre and RLT – Road and Lane Topology Services**

C-Roads Platform (C-Roads 2017c) service introduction and use cases: “The service is to provide information to road users for a safe and efficient crossing of an intersection. Objective is more attentive driving while approaching and passing an intersection by providing in-car information and speed advice for better energy efficiency and improved road safety.

Use Cases:

- GLOSA – Green light optimal speed advisory
- Signal Phase and Timing and Map Data Message
- Signal violation
- Intersection Safety”

### 4.1.4. Other relevant C-ITS architectures

**ECo-AT (European Corridor – Austrian Testbed for Cooperative Systems) is part of the EU Cooperative Corridor, Netherlands-Germany- Austria** is the Austrian project to create harmonised and standardised cooperative ITS applications jointly with partners in Germany and the Netherlands. 3rd parties have access to the published system specifications. The main objective of the project ECo-AT (www.eco-at.info/) is to close the gap between research and development and the deployment of cooperative ITS services by definition of all necessary elements deployment of day-1 services.

The common specifications and results of the EU cooperative Corridor are also included in the C-ROADS service specifications and communication profiles.

**US Department of Transportation (USDOT)** has recently published the Architecture Reference for Cooperative and Intelligent Transportation. The architecture is a support to the initiated pilot projects in the US and is available from the Connected Vehicle Reference Implementation Architecture (CVRIA) website (http://local.iteris.com/cvria/) and it will remain online through the life of the USDOT’s Connected Vehicle pilots.
4.2. C-ITS communication technologies

The communication technologies for C-ITS are based on standards which are developed by the Standards Development Organizations (SDO). ETSI (the European Telecommunications Standards Institute), CEN (the European Committee for Standardization) and ISO (International Organization for Standardization) are the most important standardisation organisations as they produce the most C-ITS standards relevant for the European market. Please refer to chapter Error! Reference source not found. for more details.

The communication technologies for C-ITS can very generally be specified as “short-range” and “long-range” communication networks, which both imply a series of communication characteristics and which complement each other in the C-ITS domain with the necessary link between road infrastructure in various operating environments and the vehicles and the personal C-ITS Stations. Hereby the short-range network supports safety relevant direct communication between stations and needs roadside units in dense transport networks, whereas long-range communication will be implemented by cellular networks with different generations of technology. In addition, in the light of the future connecting vehicles this combination of complementing communication networks adds reliability in the case one network is in a specific situation not fully operational. Examples of the communication networks are the following:

4.2.1. Short-range communication, ITS-G5 / IEEE 802.11p

The CAR 2 CAR Communication Consortium (C2C-CC) provides a short overview of the ITS-G5 technology: “The communication technology for cooperative ITS and Car-2-Car Communication is derived from the standard IEEE 802.11, also known as Wireless LAN and a frequency spectrum in the 5.9 GHz range has been allocated on a harmonised basis in Europe in line with similar allocations in USA. As soon as two or more vehicles or ITS stations are in radio communication range, they connect automatically and establish an ad hoc network. As the range of a single Wireless LAN link is limited to a few hundred meters, every vehicle is also router and allows sending messages over multi-hop to farther vehicles and ITS stations. The routing algorithm is based on the position of the vehicles and is able to handle fast changes of the ad hoc network topology.” (C2C-CC 2017)

ETSI technical report provides additional details of the IEEE 802.11p technology: “The radio interface of ITS-G5 is specified in ETSI EN 302 571 and ETSI EN 302 663. It is based on IEEE 802.11 and uses a 10 MHz channel bandwidth Orthogonal Frequency-Division Multiplexing (OFDM) signal. The default configuration uses a Quadrature Phase Shift Keying (QPSK) modulation of the OFDM carriers with a coding rate of 1/2. The resulting data rate is 6 MBit/s. The transmit power level is limited by regulation to 33 dBm, and the default value is 23 dBm. ITS-G5 uses the CSMA/CA MAC protocol as specified in IEEE 802.11. Packet prioritization is done by the EDCA mechanism with four different access categories as specified in IEEE 802.11. Decentralized Congestion Control (DCC) is a mandatory
component of ITS-G5 stations operating in ITS-G5A and ITS-G5B frequency bands to maintain network stability, throughput efficiency and fair resource allocation to ITS-G5 stations. A set of access layer DCC mechanisms has been specified in ETSI TS 102 687.” (ETSI 2016)

ITS-G5 short-range communication has been developed especially for low-latency time-critical safety C-ITS services. From 2019 on the first set of C-ITS applications, the so-called “day one services” will be implemented in the road network of more than 10 countries in Europe and by the members (vehicle manufacturers) of the C2C CC.

4.2.2. Short-range communication, Cellular V2X

During recent years, 3GPP has had an activity to define and specify a LTE based V2X system. With this activity, 3GPP was defining cellular based alternatives for already existing IEEE802.11p based C-ITS systems. 3GPP developed functionality to provide vehicular communications - both in terms of direct communication (between vehicles, vehicle to pedestrian and vehicle to infrastructure) and for cellular communications with networks. The Cellular Vehicle-to-Everything (C-V2X) standard, for inclusion in the Release 14, was completed in 2016. As part of Release 14, the 3GPP has included a technology for direct short-range V2V communication operating in ITS bands (e.g. ITS 5.9 GHz) which can work also independent of cellular network. (3GPP 2016)

As stated in the white paper from the 5GAA (5GAA 2017), C-V2X - as part of the 3GPP standards family - offers an evolution path from LTE based C-V2X (Rel. 14) to 5G. However, the readiness and timetable of the C-V2X technology for real world deployment is still unclear and decisions to deploy the C-V2X have not been taken yet. Several pilots with C-V2X technology has been started during 2017 in Germany (Qualcomm 2017a), France (Ericsson 2017), USA (Qualcomm 2017b), Japan (Qualcomm 2018) and China (Continental 2017).

4.2.3. Long-range communication, Cellular

C-ITS utilise the existing cellular networks (3G, 4G LTE) for long-range communication. The cellular technologies are used for connecting vehicles to infrastructures via cloud services and backend interfaces (vehicle-to-network). According to the European Commission communication (European Commission 2016a), the way forward with the C-ITS deployment is through a hybrid communication approach, i.e. by combining complementary communication technologies. Currently, the most likely hybrid communication mix is a combination of ETSI ITS-G5 and existing cellular networks. This enables full support for deployment of all Day 1 C-ITS services. It combines low latency of ETSI ITS-G5 for time-critical safety-related C-ITS messages with wide geographical coverage and scalability of access to large number of devices of existing cellular networks.
4.3. C-ITS Security

In the first phase of the EU C-ITS Deployment platform security was one of the main topics with the agreement of a single trust model in Europe based on a PKI – Public Key Infrastructure was achieved at expert level, which has in the mean time also been incorporated in the EU Strategy for cooperative systems (KOM2017/766). Based on this Trust model a common security Certificate Policy (CP) has been defined and is available as the basis for stakeholders to participate in the future C-ITS Network. First security functionalities for ITS-G5 is based on the ETSI TS 103 097, were also references to other standards of the security domain are mentioned. (ETSI 2016)

The Commission has published the first version of the European C-ITS Certificate Policy on its website in June 2017. This is a result from the C-ITS platform. This report (European Commission 2017b) defines the certificate policy for C-ITS data communication scenarios in following way: “For many data communication scenarios, it is very important to verify the authenticity and integrity of the messages containing information such as position, velocity and heading. This authenticity and integrity allows to assess the trustworthiness of this sent information. At the same time, the impact on privacy of road users should be minimized. To ensure those main objectives, security architecture with support of a Public Key Infrastructure (PKI) using commonly changing pseudonym certificates, has been developed. The certificate policy defines the European C-ITS Trust model based on Public Key Infrastructure. It defines legal and technical requirements for the management of public key certificates for C-ITS applications by issuing entities and their usage by end-entities in Europe. The PKI is composed at its highest level by a set of root CAs “enabled” by the Trust List Manager (TLM), i.e. whose certificates are inserted in an European Certificate Trust List (ECTL), which is defined and published by the central entity TLM. “

For further information: In CAPITAL Topic Study 9 (Information security, data protection and privacy) there are (two) case studies, discussing implementation issues related to C-ITS data protection and privacy.
5. ITS and C-ITS Standards

5.1. About Standardization

Standards are published technical documents on specifications, definitions, and procedures that are understood, implemented, and adopted by, in the ideal scenario, all in a given market. They guarantee interoperability, compatibility, safety, functionality of the product or service, method, material themselves and in connection to others. (IEEE-SA n.d., ISO n.d.).

By using standards, the development of the product, service, method or material can be simplified and made faster, the final products can be more easily compared and they can be deployed or sold internationally given that the standard has spread and been adopted globally. This reduces the cost of production and increases product quality, safety, interchangeability, and interoperability. (IEEE-SA n.d., ISO n.d.).

Standards are also important in verification and validation, as the verification or validation process can itself be standardized (e.g. IEEE 2017). Thus any product that has passed the verification process can be trusted to meet its requirements and regulations.

Standards are developed together by all interested parties under a Standards Development Organization (SDO) by following their standardization process. The development process of standards varies between different SDOs, but in general, they roughly follow a consensus-driven process of:
1) An idea is formally proposed by an entity to the SDO
2) The proposal is evaluated by the SDO and if it passes the SDO will help and oversee the development process, but the proposing entity will be responsible for the development itself
3) The proposing entity will organize a team to develop the standard in accordance to the rules and processes of the SDO
4) The team will iteratively work on drafts of the standard, communicate, and solve the issues raised, in accordance to the rules and processes of the SDO
5) Once the team has finalized the standard, it is submitted for approval and will go through the hierarchy determined by the SDO
6) When every stage in the hierarchy has reviewed and accepted the final iteration of the standard, it is published and distributed
7) The standard will go through further revision after publication based on feedback, changing market conditions, and other factors. (IEE-SA n.d., ISO n.d.).

Details on the exact development processes of different SDOs can be read from their websites. For example:
- ISO: https://www.iso.org/developing-standards.html
- CEN: https://www.cen.eu/work/ENdev/how/Pages/default.aspx

Below is a list of some relevant Standards Development Organizations, their scope and conventions. After that, some relevant standard in ITS and C-ITS are presented.

5.2. Standardization organisations

ETSI, CEN and ISO are the key standardisation organisation for C-ITS in Europe. Already in 2014 CEN and ETSI confirmed that the basic set of standards for Cooperative Intelligence Transport Systems (C-ITS) have been adopted and issued. However, the development of C-ITS standards in ETSI and CEN has continued.

5.2.1. ETSI

ITS committee (TC ITS) is developing global standards for C-ITS. ETSI TC ITS role is described in their web site (ETSI 2017): “ETSI TC ITS develops standards related to the overall communication architecture, management (including e.g. Decentralized Congestion Control), security as well as the related access layer agnostic protocols: the physical layer (e.g. with ITS-G5), Network Layer, Transport Layer (e.g. with the GeoNetworking protocol), Facility Layer, (e.g. with the definition of facility services such as Cooperative Awareness - CA, Decentralized Environmental Notification - DEN and Cooperative Perception – CP, used by the ITS applications). Other addressed topics include, among other things, platooning, specifications to protect vulnerable road users such as cyclists and motor cycle riders, specifications for Cooperative Adaptive Cruise Control as well as multichannel operation.”
ETSI produces standards, specifications and reports for different purposes. These different types of standards are produced according to their corresponding purposes and the time needed to draft and approve them:

- European Standard (EN)
- ETSI Standard (ES)
- ETSI Guide (EG)
- ETSI Technical Specification (TS)
- ETSI Technical Report (TR)
- ETSI Special Report (SR)
- ETSI Group Report (GR)
- ETSI Group Specification (GS)

The Technical Committee for Intelligent Transport Systems (ITS) addresses all ITS-related aspects from Application down to the lower communication layers. ETSI standards are available from the ETSI web site: http://www.etsi.org/standards-search

5.2.2. CEN

CEN, the European Committee for Standardization is one of three European Standardization Organizations (together with CENELEC and ETSI) that have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level.

CEN TC278-WG16 / ISO TC204-WG18 are the working groups responsible for development of C-ITS related standards, which are non-safety related Infrastructural use cases. CEN is developing related standards in direct cooperation with ISO. All standards will be categorized as World standards and are distributed by ISO. On a global level the corresponding standardization is handled by ISO/TC 204 'Intelligent Transport Systems'. Several standards are developed in conjunction with ISO/TC 204. This shows the alignment of the CEN and ISO working groups related to ITS. http://www.itsstandards.eu/
CEN/TC 278 is responsible for managing the preparation of standards in the field of Intelligent Transport Systems (ITS) in Europe. It serves as a platform for European stakeholders to exchange knowledge, information, best practices and experiences in ITS. CEN/TC 278 have liaisons with ETSI TC ITS (www.etsi.org/) and ISO/TC 204 (www.iso.org/). The European Telecommunications Standards Institute (ETSI) produces globally-applicable standards for Information and Communications Technologies. ETSI and CEN cooperate in a number of fields.

CEN standards can be found from the CEN web site: https://www.cen.eu/Pages/default.aspx

5.2.3. IEEE

The Institute of Electrical and Electronics Engineers (IEEE) Working Group 1609 provides standards for Wireless Access in Vehicular Environments (WAVE) which defines architecture and standardized set of services and interfaces for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications. IEEE 802.11 is the WiFi communication standard. This standard provides the lower layer standard (MAC-PHY) used within C-ITS communication in Europe (and USA). For Europe the ITS-G5 protocols run on
top of the IEEE 802.11 including the 11p amendment (required for ITS-G5). These standards are fundamental to the operation of ITS-G5. (Spaanderman et al. 2014).

IEEE standards are available from the IEEE web site: http://standards.ieee.org/findstds/index.html

5.2.4. 3GPP

The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations (SDOs) across the globe and develops standards for cellular telecommunications network technologies ranging from 2G, 3G, to 4G (LTE and LTE-Advanced), and upcoming 5G. (HIGHTS 2016)

3GPP has developed functionality to provide enhancements to LTE specifically for vehicular communications - both in terms of direct communication (between vehicles, vehicle to pedestrian and vehicle to infrastructure) and for long-range cellular communications with networks. The Cellular Vehicle-to-Everything (V2X) standard, for Release 14, was completed in 2016. (3GPP 2016).

Also 3GPP standards are available from the ETSI web site: http://www.etsi.org/standards-search

5.3. Relevant Standards

To illustrate the role of standards in ITS and C-ITS, a few relevant standards are reviewed. This chapter is structured such that it starts with a standard that specifies a common architecture of different ITS sub-systems, from hand-held devices to roadside units. This offers an overview of the different functions and components of the systems. The architecture follows a common layered protocol stack design. Thus, next, a standard defining one layer from this stack is reviewed as an example. The same standard also, in general terms, defines basic C-ITS applications. The functional requirements of these applications are reviewed in the next standard. Finally, a standard covering the application requirements specification for one of these applications is reviewed. A list of other relevant standards not explained in such detail follows these chapters.

5.3.1. ETSI EN 302 665

The ETSI EN 302 665 standard (ETSI 2010b) specifies the basic architecture of communications in ITS systems. It is a common architecture that all ITS stations follow. ITS sub-systems are defined as "sub-system of ITS with ITSC components for a specific context" and they are divided into personal (e.g. hand-held devices), central (part of an ITS centre), vehicle (e.g. in cars), and roadside ITS sub-systems. Each ITS sub-system has an ITS station, which fulfills the functionality described in the ITS station reference architecture.

The architecture follows and extends the ISO OSI model (ISO/IEC 7498-1) which
characterizes the communication in a computing or communication system. It uses abstraction layers to separate different parts of the communication in a hierarchical manner. Each layer depends on the layer beneath it and provides functionality to the layer above it to the extent that the layer above needs it.

From bottom up, the layers are:

- **Access layer.** Communication interfaces, both internal and external, between physical communication channels (e.g. Bluetooth, GPS, Ethernet) and digital data links for layers above.
- **Networking & Transport.** Common networking protocols (e.g. IPv6) and transport protocols (e.g. TCP, UDP), also C-ITS specific protocols could be supported.
- **Facilities.** Supporting functionality shared by many applications of the application layer.
- **Applications.** ITS applications that are usually distributed in client and server applications. For example, "Emergency vehicle warning" would be a "Road Safety" application, where the server indicates to the client that an emergency vehicle is approaching it.

These are supported, on the sides of the stack in the architecture, by the "Management" and "Security" blocks with provide management of the communications and security services for all other blocks.

The standard also lists and specifies different ITS sub-systems, their stations, and certain types of ITS stations (host, gateway, router, border router) and how they communicate with other ITS stations and other entities within using networks. For example, the ITS-S gateway is usually connected to an ITS station-internal network and connects its facilities layer to another OSI protocol stack, which resides typically in a proprietary network.

### 5.3.2. ETSI TR 102 638

The ETSI TR 102 638 standard (ETSI 2009) defines the V2X facilities layer model and Basic Set of Applications (BSA). Facilities are defined as "functions or data which are common to several applications and are supporting them". The facilities layer model describes the functionalities that a V2X application, defined in the Basic Set of Applications (BSA), can require.

The BSA are defined as "group of mature applications (regrouped use cases), supported by a mature, relevant vehicular communication system" and are further developed in the ETSI TS 102 637-1 standard (see below). In essence, they are active road safety applications, traffic efficiency applications, and other applications that can be deployed in a cost-effective manner. They answer to the needs of several different users (e.g. vehicle owner, driver, passenger, road traffic managers, etc.) in a setting where the vehicles move at various speeds and driving conditions through different driving environments and contexts. All the
Applications use a vehicular communication system to send and receive information that enables the functionality of the application. Thus the applications operate in an environment, where there are stationary ITS stations (the infrastructure) and mobile ITS stations (e.g. the vehicles).

ITS applications are specified in an architecture that is an extension to the ISO OSI model (ISO/IEC 7498-1), in which layers are abstraction that have a set functionality that it provides for the layer above it and uses the functionality of the layer below it. The facilities layer is positioned between the applications layer (provides and defines the BSA and its services) and the networking and transport layer. The facilities in the layer are intended to provide generic support functions to the applications.

The functionalities of the facilities layer are divided into functional blocks, which form the architecture for the facilities layer. These are “Applications Support”, “Information Support”, and “Communication Support”. The Applications Support block has facilities that provide the applications information on the position of ITS stations, the current state of the ITS stations, managing of the services the application provides, managing of Local Dynamic Map (LDM) of the application (e.g. mapped information about its surroundings), managing of the messages the application sends and receives, security features, and time management. The Information Support block provides various processing facilities for the static and dynamic data the application use (e.g. conversion between data types). The Communication Support block provides the application support for different communication modes.

5.3.3. ETSI TS 102 637-1

The ETSI TS 102 637-1 standard (ETSI 2010a) defines the functional requirements for the Basic Set of Applications (BSA). They are lists of functions an application has to be engineered to perform in order to perform its intended behavior.

The standard lists 32 use cases divided into 7 applications and provides the functional requirements for these. For example, the application "Driving assistance - Road hazard warning" is intended to convey information about road hazard events to or from vehicles or roadside equipment. The information can be about the position, duration, severity, or other descriptions of the hazard event. It has 17 use cases listed for it. As an example:

- UC005: emergency electronic brake lights;
- UC006: wrong way driving warning;
- UC007: stationary vehicle warning - accident;

The messages are transmitted either as Cooperative Awareness Messages (CAM) or as Decentralized Environmental Notification Messages (DENM). They are defined in standards ETSI EN 302 637-2 (ETSI 2014b) and ETSI EN 302 637-3 (ETSI 2014c), respectively.

The functional requirements list for the use case "UC006: Wrong way driving warning" has 21 functional requirements. As an example, these include:

- [FR_UC006_004] If an ITS station detects a "wrong way driving" event, the
corresponding RHW application shall be triggered.

- [FR_UC006_005] The RHW application shall request to construct and transmit a "wrong way driving warning" DENM construction.
- [FR_UC006_010] The originating ITS station shall transmit the "wrong way driving warning" DENM at a defined transmission rate as long as the "wrong way driving" event persist.
- [FR_UC006_018_VS] Information sent included in the "wrong way driving warning" DENM shall allow a receiving vehicle ITS station to check the relevance of the "wrong way driving" event and estimate the collision risk with vehicle driving in the wrong way level.
- [FR_UC006_019_VS] The RHW application shall decide whether warning "wrong way driving warning" information should be provided via HMI.

Thus, the standard does not provide a specification for the development or the implementation of the application use cases, but is intended to serve as a reference document on the functionality that the deployed implementation should contain.

**5.3.4. ETSI TS 101 539-1**

The ETSI TS 101 539-1 standard (ETSI 2013) covers the application requirements specification for the Road Hazard Signaling (RHS) application mentioned in the previous chapter. It divides the application into two different functional modes: (i) detection and signaling or road hazard events, and (ii) receiving messages about road hazards. Or, originating mode and receiving mode, respectively. The standard also defines a performance classification system for the incident data based on the age of the data. Performance class A is given if the time between data acquisition and positioning data acquisition (with 1 meter accuracy) is less than 150 milliseconds. Class B is given, if the time difference is less than 1.4 seconds.

The standard states that the main function provided by the originating RHS application are (i) generation and signaling of a Decentralized Environmental Notification Messages (DENM) when a road hazard is detected, and (ii) setting a priority level for the situation if the data conforms to the performance class A. The priority level describes if the originating vehicle is in a pre-crash situation, warning situation, or is not in a critical safety situation.

The receiving RHS application receives all the different kinds of messages, processes them, and makes a decision, based on the accuracy, age, confidence level, and other such quality measures, on how best make use of the received messages. It could, for example, flash a warning sign to the user of the ITS station in question.

The standard describes the functional requirements for the use cases of the RHS application and details the data elements and their values that are included in the transmitted DENM. It also details the application operational requirements for the RHS. These, again, use the classification into performance class A and B. The requirements are lists of functions and behaviors the application shall and shall not do in a given situation as well as different failure
and attack situation it needs to take into account.

5.4. Other standards

Here is a short list of other relevant C-ITS standards:

- ETSI TS 102 724: "Intelligent Transport Systems (ITS); Harmonized Channel Specifications for Intelligent Transport Systems operating in the 5 GHz frequency band".

- ETSI EN 302 571: "Intelligent Transport Systems (ITS); radio communications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

- ETSI TS 102 636 (all parts): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking".

- ETSI TS 102 723 (all parts): "Intelligent Transport Systems; OSI cross-layer topics".

- ETSI EN 302 637-3 (V1.2.0): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

- ISO/IEC 212177: "Intelligent Transport Systems - Communications access for land mobiles (CALM) - Architecture".

Security related standards:

- ETSI TR 102 893 V1.2.1 (Published 2017-03). “Security; Threat, Vulnerability and Risk Analysis (TVRA)”

- ETSI TS 103 097 V1.2.1 (Published 2015-06). “Security header and certificate formats”. This standard defines the security applied to the V2X messages exchanged between the On-board Unit (OBU) and the Road-side unit (RSU) via V2X communication in the use cases.

Relevant eCall standards:

- CEN EN 16072 (2015): "Intelligent Transport Systems - eSafety - Pan European eCall operating requirements".

- CEN EN 15722 (2015): "Intelligent Transport Systems - eSafety - eCall minimum set of data (MSD)"
6. Using standards and interoperability

6.1. Profiles

Profiling is described briefly in a report from the Rijkswaterstaat in Netherlands (Spaanderman et al. 2014): “In standards elements are defined which shall always be implemented and elements which “may” (options) be implemented. This means that standards cannot be used without alignment among the stakeholders, on how and what to use it in case of options. To ensure interoperability and conformity, alignment is required within the community of stakeholders using them. Therefore their agreement is needed on these options. These decisions are captured within a Profile. A profile includes the minimum set of requirements, referencing to those standards used. For the domain of C-ITS this is extremely important to ensure interoperability and conformity for all stakeholders.”

C-Roads Platform Workgroup Technical aspects is currently working towards a common C-ITS profile. The target is to achieve interoperability based on the commonly specified communication profile. In September 2017 C-Roads published the first release of the harmonised communication profile for Cooperative Intelligent Transport (C-ITS) services based on the respective ETSI and CEN standards. The first release focuses on the communication profile for IEEE 802.11p/ETSI ITS-G5 short range communication and I2V (Infrastructure-to-Vehicle) communication for high level Day-1 Services. (C-Roads 2017a).

6.2. Guidelines

In addition to standards, there are various guidelines to help developers to implement interoperable and safe to use ITS applications and service. Here are two examples described:

6.2.5. ITS Deployment Guidelines

The ITS Deployment Guideline fact sheet (EU EIP 2015) describes the guidelines as follows: “European road authorities and road operators have teamed up to unlock the benefits of cooperation and harmonisation in the deployment of Intelligent Transport Systems (ITS) on Europe’s major road network. Fragmented deployment on a national level will fail to deliver seamless European services and will not contribute to a coherent European Transport network at the end. The Member States – co-financed by the European Commission – have consequently developed a set of Deployment Guidelines (DG) created jointly by ITS experts and practitioners. The guidelines have undergone a thorough review by international domain...
experts in an intense peer review and they have been validated by the Member States in an extensive formal Member State consultation and mediation process, which finally led to their adoption as basis for all future European harmonised ITS deployment activities.

**The harmonisation concept**
Based on a Pan-European accepted understanding of the nature and the benefit of each ITS-service, European Added Value is generated through three main elements:

1. Interoperability in terms of functional, organisational and technical features to harmonise cooperation and collaboration between different road operators and other third parties involved in the deployment and operation of an ITS-service;
2. Common Look & Feel to present ITS-services to the road user in a harmonized European way;
3. European-wide accepted assessment criteria to offer assessment against the background of harmonized level of service and operational environment criteria.

Examples of the harmonized ITS services was introduced in chapter Error! Reference source not found.

### 6.2.6. HMI guidelines

Human-Machine Interaction (HMI) guidelines and standards have been developed in order to promote safe and usable in-vehicle systems and applications. The European Statement of Principles on HMI (ESoP) incorporates principles formulated as generic goals to be achieved by the design of a safe and user-friendly HMI of in-vehicle information and communication systems which have been intended to be used by the driver while driving. These principles of the ESoP are organised into 6 groups (Deserve 2013):

1. Design goals
2. Installation principles
3. Information presentation principles
4. Principles on interaction with displays and controls
5. System behaviour principles
6. Principles on information about the system

HMI related standard ISO ISO 9241-210:2010 Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems provides requirements and recommendations for human-centred design principles. The standard is intended to be used in the design processes. (ISO 2010).

### 6.3. Testing and Interoperability

Testing and interoperability is defined in ETSI web site (ETSI 2018) in following way: “In a world of converging yet diverse technologies, complex ICT systems must communicate and
interwork on all levels – this is interoperability. One of the key motives for the development of ICT standards is to facilitate interoperability between products in a multi-vendor, multi-network and multi-service environment. In addition, standards themselves need to be designed and tested to ensure that products and services complying with them do indeed achieve interoperability. Testing of products and systems to verify their interoperability is critical to their success – ideally this should take place throughout their development. Eliminating basic interoperability problems at an early stage helps reduce costs and avoid dissatisfied customers. A standardized approach to testing is essential if the results are to be trusted. Testing is an important part of providing a guarantee of interoperability. As an example ETSI focuses on two different, complimentary types of test activity: conformance testing and interoperability testing. The feedback from interoperability events is also extremely valuable in helping to validate the standards themselves.”

6.4. Certification

Certification can be seen as a specific form of compliance assessment. Standard ISO/IEC/IEEE/24765 defines certification as follows (IEEE 2010):

“1. a written guarantee that a system or component complies with its specified requirements and is acceptable for operational use, 2. a formal demonstration that a system or component complies with its specified requirements and is acceptable for operational use, 3. the process of confirming that a system or component complies with its specified requirements and is acceptable for operational use.
EXAMPLE a written authorization that a computer system is secure and is permitted to operate in a defined environment”

6.5. Compliance assessment

The C-ITS Platform final report from Phase II (European Commission 2017c) provides description for compliance assessment for C-ITS: “The aim of the work on Compliance Assessment was to define a top-level approach and methodology for testing and validation. This included evaluating and issuing recommendations on how this compliance assessment can be achieved, with a specific focus on C-ITS stations, and on the necessary legal and organisational frameworks for the setup and the operational phase of the C-ITS network.” The report provides an overview of the compliance assessment process for C-ITS which is depicted in Figure 6.
7. Discussion and conclusions

This topic study addressed ITS and C-ITS communication technologies and standards. ITS is already established and widely used by road users, private companies and public road operators and authorities. C-ITS is coming to the market. The Day 1 (and later 1.5 C-ITS) services have been identified as priority. The C-Roads Platform lead by the European road operators and authorities is working actively to harmonise the deployment of these first C-ITS services across the Europe. The target is to have the final open issues solved and launch the commercial C-ITS services in 2019. The first deployments of C-ITS will be based on hybrid communication utilising ITS-G5 and existing cellular networks. It will be interesting to see how extensively the Day 1 services will be deployed and how widely they are supported by the vehicle manufacturers. In addition, it will be exciting to follow how the development of cellular V2X will go forward in coming years, how it will work together or parallel with short-range ITS-G5 technology and when they will be deployed on the market. In any case, the C-ITS services will be utilised more and more in the future.
8. References


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