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## **ICT Infrastructure-based cooperative and connected systems for intelligent European road transport**

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### **Abstract**

The development and deployment of C-ITS (Cooperative Intelligent Transport Systems) aims at making road transport safer (for all road users, including VRUs - Vulnerable Road Users), more efficient and more environment-friendly. The project C-MobILE (Accelerating C-ITS Mobility Innovation and depLoYment in Europe) aims to stimulate large-scale, real-life and interoperable C-ITS deployments across Europe. It will establish large-scale deployment of sustainable services in complex urban areas with the support of local authorities, and ensure interoperability and seamless availability of high quality bundled services for end-users, that will be successful from a business perspective. The C-MobILE operational procedures will lead to decentralised and dynamic coupling of systems, services and stakeholders across borders in an open but secure C-ITS ecosystem, based on different access technologies, the use of which is transparent for service providers, and seamless and continuous for end-users across different transport modes, environments and countries. This paper presents some preliminary results, which are the starting basis of C-MobILE, including recently developed architecture, strategies and partnerships for C-ITS deployment, followed by some discussions.

### **Keywords:**

C-ITS, deployment, services, bundling

### **Introduction**

Intelligent Transport Systems (ITS), based on ICT (Information and Communication Technologies), for road transport are rapidly developing since more than three decades, with the aim to improve safety, traffic efficiency, energy efficiency and comfort [Lu (Ed.), 2016]. The core technologies in the ITS domain are sensor technology, telecommunications, information processing and control technology. Various technologies can be combined in different ways to create stand-alone in-vehicle systems and

cooperative systems (V2X). The perspective of C-ITS [C-ITS Platform, 2016] is that ICT infrastructure-based cooperative, connected and automated driving is an option for enhancing traffic safety, traffic efficiency and energy efficiency, and for reducing fuel consumption. Potential C-ITS services are presented in Table 1.

**Table 1** - C-ITS services [C-ITS Platform]

List of Day 1 services	List of Day 1'5 services
<p><b>Hazardous location notifications:</b>                      Slow or stationary vehicle(s) &amp; Traffic ahead warning                      Road works warning                      Weather conditions                      Emergency brake light                      Emergency vehicle approaching                      Other hazardous notifications</p> <p><b>Signage applications:</b>                      In-vehicle signage                      In-vehicle speed limits                      Signal violation / Intersection Safety                      Traffic signal priority request by designated vehicles                      Green Light Optimal Speed Advisory (GLOSA)                      Probe vehicle data                      Shockwave Damping</p>	<p>Information on fuelling &amp; charging stations for alternative fuel vehicles                      Vulnerable Road user protection                      On street parking management &amp; information                      Off street parking information                      Park &amp; Ride information                      Connected &amp; Cooperative navigation into and out of the city (1st and last mile, parking, route advice, coordinated traffic lights)                      Traffic information &amp; Smart routing</p>

The project C-MobILE (Accelerating C-ITS Mobility Innovation and depLoyment in Europe) aims to stimulate large-scale, real-life and interoperable C-ITS deployments across Europe. It will establish large-scale deployment of sustainable services in complex urban areas with the support of local authorities, and ensure interoperability and seamless availability of high-quality services for end-users, that will be successful from a business perspective. The C-MobILE operational procedures will lead to decentralised and dynamic coupling of systems, services and stakeholders across borders in an open but secure C-ITS ecosystem, based on different access technologies, the use of which is transparent for service providers, and seamless and continuous for end-users across different transport modes, environments and countries. C-ITS services (bundles) will be fully demonstrated on eight pilot sites: Barcelona (ES), Bilbao (ES), Bordeaux (FR), Copenhagen (DK), Newcastle (UK), North Brabant Region (Helmond, Eindhoven) (NL), Thessaloniki (EL) and Vigo (ES).

The next section provides a short introduction about the concept and approach of C-MobILE. A generic architecture is initiated. Challenges, strategies and partnership for large-scale C-ITS deployment are discussed. Further innovation actions in C-ITS are presented. Finally conclusions are drawn.

## **C-Mobile concept and approach**

C-Mobile will demonstrate C-ITS solutions at large-scale in urban and extra-urban environments, by providing services to several end-users' groups (including VRUs - Vulnerable Road Users) across various transport modes. It will address real-life mobility issues and achieve business cases for the entire surface transport system based on sustainability criteria. This will be achieved by opening up existing ITS-enabled cities via a hybrid C-ITS communication architecture (i.e. integrating current V2X communication technologies) and by providing clustered C-ITS services and applications in a seamless, uninterrupted cross-modal and cross-border way.

The C-Mobile architecture will:

- 1) solve the common challenges of secure, private and reliable communication for C-ITS;
- 2) provide a standardized mechanism for service delivery of C-ITS applications;
- 3) ensure compatibility between existing C-ITS deployments across various cities / regions and serve as baseline for uptake in new locations.

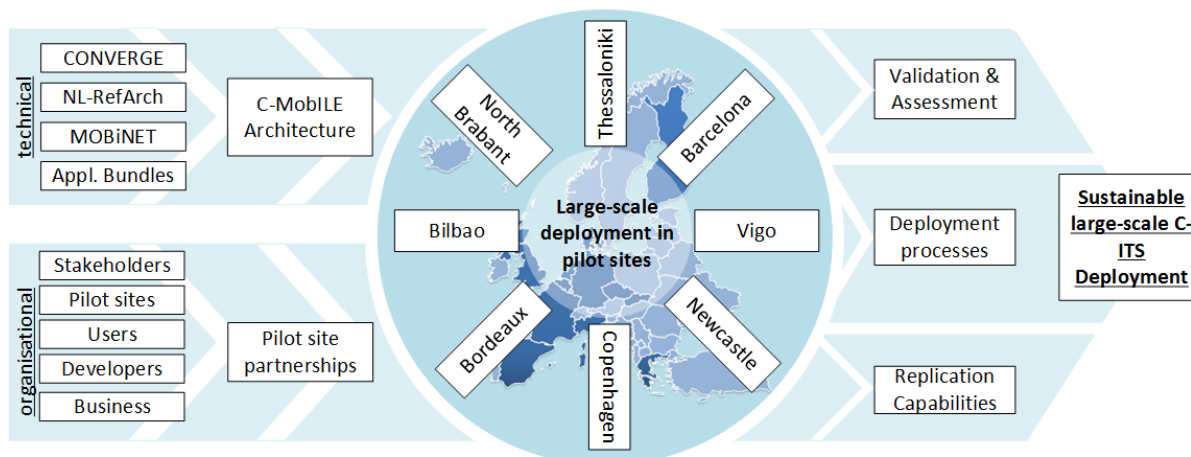
Technology alone is not sufficient to ensure sustainable deployment of C-ITS. C-Mobile will address stakeholder partnerships for sustainable operation such as road operators (e.g. public authorities, highway agencies), service providers (e.g. public transport operators) and representatives for users (including VRUs) in order to establish a functioning partnership in and around engaged community around every C-ITS deployment site.

C-Mobile clusters C-ITS applications into four thematic bundles identified according to their relevance to pilot sites, feasibility and potential for market uptake. The bundling concept ensures a seamless service to end-users, maximises impact and reduce investment costs, and enables integration of existing applications through a multi-variant optimisation of properties of the individual applications. C-Mobile applications bundling is presented in Table 2.

The overall approach of C-Mobile is illustrated in Figure 1. C-Mobile adopts state of the art technologies in terms of communication, road-side architecture, and service delivery concepts to define an architecture that is cross-border interoperable, utilizing hybrid communication technologies. A series of C-ITS applications are demonstrated using the C-Mobile architecture by involving stakeholders, operators of the pilot sites, developers of user device solutions and large user communities. The results of the pilots will be extensively validated on the technical aspects and user / societal impacts. The procedures for large-scale deployment will be defined and validated through the functioning stakeholder partnerships by following a step-wise approach that combines technical and business perspectives. This will lead to large-scale C-ITS deployment on all the C-Mobile pilot sites, and replication to other cities by publishing deployment guidelines.

**Table 2** - An overview of bundles and applications in C- Mobile

Bundle 1: urban efficiency	Bundle 2: infrastructure-to-vehicle safety
Rest time management Motorway parking availability Urban Parking availability	Road work warning Road hazard warning (incl. traffic jams) Emergency Vehicle Warning Signal Violation Warning Warning system for pedestrian (not limited to crossings)
Bundle 3: traffic efficiency	Bundle 4: vehicle-to-vehicle safety
Green priority Green light optimal speed advisory (GLOSA) / "Dynamic eco-driving" Cooperative traffic light for pedestrian Flexible infrastructure (HOV, peak-hour lanes) Mode & trip time advice (e.g. by incentives) Probe Vehicle Data	Emergency Brake Light Cooperative (Adaptive) cruise control (Urban ACC) Slow or Stationary Vehicle Warning Motorcycle approaching indication In-vehicle signage (e.g. Dynamic speed limit) (including other VRUs) Blind spot detection / warning (VRUs)

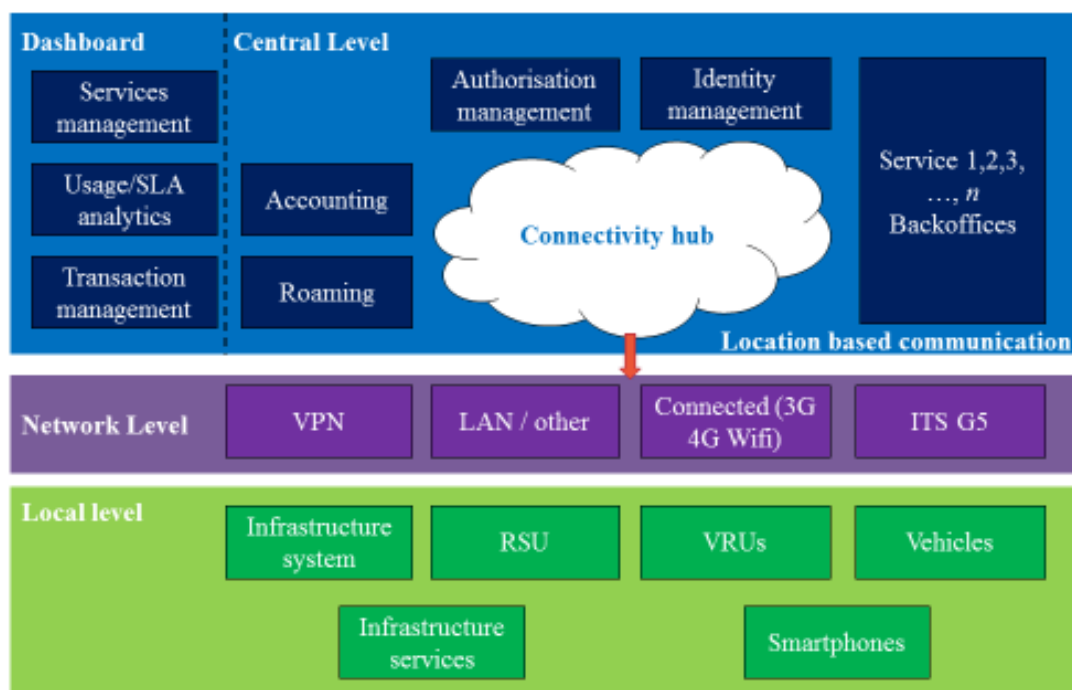


**Figure 1:** C-Mobile approach

**C-Mobile generic architecture**

C-Mobile builds on the architecture of both MOBiNET and CONVERGE and aims to be compatible with both. The main difference between the two architectures is that MOBiNET is mostly focused on an (Info-structure) platform providing components and tools such as sophisticated Service Directory, Identity Server and communication agent, including payments and billing. This will be used to allow easy access to new application bundles. CONVERGE, on the other hand, has developed a technical and operational framework of a cooperative architecture for V2X-communication including a security concept and hybrid communication. This means the two architectures are complimentary.

A generic C-MobILE architecture is proposed (see Figure 2). On the central level, the architecture is built around the connectivity hub. This hub is based on Internet of Things (IoT) technology and ensures data is shared on a topic level. This means there are no direct connections between communicating nodes, which guarantees the security. At the same time the access to the topics is managed to only let authorized identities read or write them. When a service is paid, the identity and authorization is most important as the accounting component will keep track of which actors have to pay to others for the content or services. Roaming is a special platform service connecting two services in different geographical areas to each other to provide a seamless experience to the end-users as they can still use the app / service they are used to. Service specific back-offices do not need to be at the same location as the connectivity hub and can be connected through the cloud. Each service provider has access to a dashboard to manage how their services interact with the platform. Hence, the bundling of applications further enhances the C-ITS services efficiency in a seamless way.



**Figure 2:** High level architecture for C-MobILE

On the network level, the architecture supports any communication technology. VPN is generally used to connect to infrastructure systems in the field as a direct connection through the cloud would not satisfy their security requirements. Even a dedicated LAN could be utilized for this. Connected communication is the backbone of the network level in this architecture, the topic structure on the central level also supports this well. For example, when data from a road-side unit (RSU) has to be sent to many vehicles in the vicinity, the RSU has to write the data only once. With location based

communication the hub will ensure it will be sent to all vehicles for which the message is relevant. The RSU will not even need to have knowledge of the amount of vehicles to which the message has been sent. ITS-G5 communication can be used to broadcast messages locally by having the central level relaying the message to local the RSUs.

On the local level many different end-users are supported. The infrastructure provides data and services, while vehicles can be reached by on-board communication technology (IEEE 802.11p and cellular network). All road users, including pedestrians and bicycles can be reached easily through a connected device like a smartphone. This is also the level where the effect of applications like GLOSA, roaming for parking apps, road hazard warning and route recommendations will be visible.

### **Strategies and partnerships for C-MobILE deployment**

Partnerships establishment and development are the key factors to enable large scale C-MobILE deployment. C-MobILE will elevate existing research pilot sites to large-scale deployment locations of sustainable services with the support of local authorities and operators. A common approach that ensures interoperability and seamless availability of services towards acceptable cost for end-users and a positive business case for all parties in the supply chain will be pursued. C-MobILE will initiate large-scale pilots early in the project to assess how mobility will develop during the extension of existing and new C-ITS services. C-MobILE will engage from the start with both private and public stakeholders, including end-users, in order to enhance C-ITS services during its execution and to establish functioning partnerships beyond the project duration and initial consortium. C-MobILE will deliver comprehensive (ex-ante and ex-post demonstration) cost-benefit analyses, business models and understanding of end-user needs related to service availability and uptake that are vital for large-scale deployments and real market roll-out.

C-MobILE will develop a framework for proposing deployment enabling solutions via setting up a Stakeholders Forum for joint public-private business partnerships, to tackle common challenges and opportunities and offer a sustainable architecture and development platforms for C-ITS applications. The C-ITS framework will include solutions for organizational concepts, legal aspects, certification, privacy, security, liability, data ownership, end-user acceptance and transitional aspects (low penetration rate benefits). This framework will also support global standardisation and harmonisation activities by cooperating with European and global decision making and standardization bodies.

C-MobILE brings together the entire ecosystem of C-ITS stakeholders and creates communities comprised by all key stakeholders in the business value chain: city authorities, policy makers, service-, technology- and telecoms providers, vehicle fleets, user associations, innovation agencies, and various categories of end-users (both professional and private citizens). Such stakeholders will contribute to create the C-MobILE C-ITS Framework paradigm and to the achievement of project objectives, by

committing actively to the extended, viable and interoperable deployment of C-ITS across Europe. C-MobILE will actively support existing and new collaborations and formulation of formal and informal partnerships (depending on country and city specific arrangements), so that deployment and uptake of C-ITS are widely supported. Furthermore, C-MobILE is going to adopt an innovative C-ITS architecture, and enable the use of multi-source datasets and address key safety and efficiency issues. The architecture will promote interoperability and will also allow for improved use of and accessibility to data in the road transport domain. Thus, the project is expected to actively contribute to further innovation for the formation of sustainable collaborative schemes between all involved stakeholders. C-MobILE will finally strongly promote an active and mutually beneficial dialogue with related experts and entities who are at the forefront of C-ITS in the USA and internationally, fostering a structured and harmonized dialogue for continuous knowledge and experience exchange, also in relation to the development of harmonised validation methodologies.

The approach of C-MobILE is expected to significantly contribute to increased innovation in the value chain of all involved stakeholders (i.e. products and services, business development and exploitation, policy, and processes). Specifically:

- 1) Products and services: C-MobILE will extend the capabilities of existing products and services in the C-ITS marketplace and develop new ones. The most significant contribution of C-MobILE in this innovation domain will be the bundling of C-ITS applications, the implementation of these bundles as well as the provision of the necessary means for further development of innovative products, services and applications in the connected C-ITS domain.
- 2) Business development: C-MobILE will support innovative business models, necessary primarily for the involved private sector entities and industries, but also for public sector stakeholders. New business models are needed for the large-scale deployment of C-ITS and the wide adoption of C-MobILE outcomes (incl. deployment guidelines) by other cities and regions, which is a concrete activity on which the project will provide significant contributions. C-MobILE will also create viable and “functioning” partnerships, needed for innovative business development within the complex C-ITS domain.
- 3) Policy: C-MobILE will support all relevant policies and priorities (e.g. ITS Directive 2010/40/EU and its Delegated Acts), including the provision of feedback for potential policy related improvements in the future at local, regional and pan-European level.
- 4) Processes: C-MobILE will develop an innovative assessment methodology as well as deployment guidelines, both of which will significantly improve relevant operational and decision making processes for all involved stakeholders.
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## **Further innovation actions and expected results**

C-MobILE will directly provide benefits to the European private sector entities that are active in the transport and mobility domain, by supporting the development of innovative products and services. Applications bundling will allow them increase their competitiveness by extending relevant markets and speeding up roll-out pace (at national, EU and global levels). Public and private stakeholders involved will have competitive advantages by being part of an integrated C-ITS framework (or ecosystem), which will be realised by C-MobILE upon the successful execution of the project, and will bring forward beyond the life span of C-MobILE by city-led business partnerships.

Further innovation actions are:

- 1) C-ITS (Cooperative Intelligent Transport Systems) framework defined in partnerships with major stakeholders for proposing key deployment enabling solutions on existing pilot sites, including business cases
- 2) Strategic Research Agenda defined for key researching and innovation areas that promote sustainable C-ITS deployments and will lead towards automated transport in Europe
- 3) Assessment including CBA (Cost-Benefit Analysis) of the cumulative real-life benefits of clustering C-ITS applications and integrating multiple transport modes in the C-ITS ecosystem
- 4) Open secure large-scale C-ITS deployment of new and existing applications demonstrated in complex urban environments interoperable across countries involving large groups of end users
- 5) Provide an open platform towards C-ITS sources to support deployment of service concepts on commodity devices, validated by developer communities
- 6) Validated operational procedures for large-scale deployment of sustainable C-ITS services in Europe
- 7) Released testing methodologies to evaluate the proven impact of C-ITS architectures and services

## **Conclusion**

Large-scale and interoperable C-ITS (Cooperative Intelligent Transport Systems) implementations will make road transport safer, more efficient and more environment-friendly. All road users (including VRUs) will get direct and tangible benefits through various C-ITS services. C-MobILE will stimulate the process of C-ITS deployments across Europe. A comprehensive approach has been carefully selected. The generic architecture will be further developed to reach the objectives of C-MobILE. Clear strategies and partnerships are determined to deploy sustainable services, which will be supported by local authorities, and to ensure interoperability and seamless availability of high-quality services for end users from a perspective of successful business. The C-MobILE operational



procedures will lead to decentralised and dynamic coupling of systems, services and stakeholders across borders in an open but secure C-ITS ecosystem, based on different access technologies, the use of which is transparent for service providers, and seamless and continuous for end-users across different transport modes, environments and countries.

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## **References**

1. C-MobILE Consortium (2017). C-MobILE (Accelerating C-ITS Mobility Innovation and depLoyment in Europe) Description of Work, C-MobILE Consortium, Brussels. (restricted).
2. C-ITS Platform (2016). Platform for the Deployment of Cooperative Intelligent Transport Systems in the EU (E03188) (C-ITS Platform) Final report, January 2016, DG MOVE - DG Mobility and Transport, Brussels.
3. Lu, M. (Ed.) (2016). *Evaluation of Intelligent Road Transport Systems: Methods and Results*. Publisher: IET (Institution of Engineering and Technology). ISBN 978-1-78561-172-8 (print), ISBN 978-1-78561-173-5 (eBook).
4. Lu, M., R.J. Blokpoel (2016). A sophisticated intelligent urban road-transport network and cooperative systems infrastructure for highly automated vehicles. In Proceedings: *World Congress on Intelligent Transport Systems*, Montreal.
5. Lu, M., R.J. Blokpoel (2016). Business model and contractual framework for implementing a pan-European e-market place of mobility services. In Proceedings: *European Congress on Intelligent Transport Systems*, Strasbourg (ERTICO-ITS Europe).
6. MOBiNET Consortium (2012). MOBiNET (interNET of MOBility) Description of Work, MOBiNET Consortium, Brussels. (restricted).
7. CONVERGE Consortium (2012). CONVERGE - Development of a technical and operational framework of a cooperative architecture for V2X-communication including a security concept and hybrid communication (2012-2015), CONVERGE Consortium, Germany. (restricted).