Next generation of Cooperative Intelligent Transport Systems

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Abstract: In the past years, significant progress has been made in the field of ITS and C-ITS at EU level. Several cooperative mobility projects (e.g. Compass4D, CO-GISTICS, CONVERGE and others) have tried to quantify and showcase the benefits of cooperative systems in increasing both energy efficiency and safety for specific transport modes. The city of Thessaloniki, Greece, and its local ecosystem of relevant stakeholders, has been engaged and has invested early on in innovation initiatives and projects, ranging from real-time infomobility solutions, to advanced traffic management and control, up to operational cooperative mobility systems and services. The city's Sustainable Urban Mobility Plan as well as the National Strategy for ITS highlight the importance for increased efforts towards the use of ITS and C-ITS in the urban and peri-urban context for Thessaloniki. In this direction, within the framework of national and EU funded research, innovation and development projects cooperative ITS technologies, solutions and systems, covering both the core urban area of the city as well as the ring road of the city have been developed. The present paper will present the main findings and lessons learnt from completed projects in the C-ITS domain as well as the next steps of the city, within the framework of the newly started C-Mobile project (H2020), where C-ITS services are provided throughout larger parts of the road network and to extended user groups, under the new concept of service bundles.

Keywords: Cooperative Intelligent Transport Systems, large-scale deployment, innovation, mobility

1. LARGE SCALE DEPLOYMENT PROJECTS IN EUROPE

In 2006, the EC launched the projects SAFESPOT, COOPERS and CVIS, all focusing on the improvement of road safety through C-ITS technologies [1], [2], [3]. Aiming for the same goal, Germany launched the project Aktiv, including also the CoCarX research initiative [4], [5]. During 2008, EU's FP7 programme funded the projects SAFERIDER, euroFOT and TeleFOT. SAFERIDER provided ADAS and IVI systems in motorcycles, while euroFOT and TeleFOT conducted FOTs for IVS and aftermarket vehicle devices [6], [7]. The INTERACTION project addressed the understanding of driver interactions, the PRE-DRIVE C2X project developed a primary common European architecture for I2V systems, while Germany, through the projects simTD and DIAMANT, envisioned to increase traffic efficiency and road safety [8], [9], [10], [11]. In 2009, the EC launched the FREILOT project, which developed C-ITS services for road goods transport [12]. At a national level, Germany as well as the Netherlands, launched two C-ITS deployment projects, Ko-FAS and SPITS respectively [13], [14].

The projects SISCOGA, eCoMove, interactIVe, OVERSEE and COSMO were launched in 2010, aiming to foster energy efficiency by developing various C-ITS services [15], [16], [17], [18], [19]. France introduced a national FOT for C-ITS standards, titled SCORE@F, while the Netherlands introduced the CCC project, with the objective of developing a cruise control system [20], [21]. A series of three projects, funded by FP7, were introduced in 2011, DRIVE C2X, PRESERVE and COMeSafety2. The projects ambitioned respectively the assessment of C-ITS through FOTs in Europe, the provision of a security subsystem for V2X communication systems and the coordination of European activities

[22], [23], [24]. In the field of FOTs, EC launched the FOTsis project and the ITSSv6 project [25], [26]. The projects Co-Cities, HeERO and COBRA were founded during the same period by the EU, while the Austrian Testfeld Telematik project and the Dutch Brabant In-Car II: ParckR project aimed for developing and operating C-ITS services at a national level [27], [28], [29], [30], [31].
In 2012, the projects MOBiNET and SEE-ITS targeted respectively in deploying an open platform for Europe-wide mobility services and stimulating cooperation in South East Europe [32], [33]. Regarding C-ITS deployment activities at a national level, Germany launched the projects CONVERGE and UR:BAN, while Finland introduced the CoMoSeF project [34], [35], [36]. During 2013, the EC proceeded in the funding of four projects, all under the FP7 programme. The P4ITS project had the goal of creating a network for the procurement of C-ITS, the VRUITS project aimed to improve the safety and mobility of VRUs, the COMPANION project focused on improving fuel efficiency and safety for goods transport, and the AutoNet2030 project headed for the development of a co-operative automated driving technology [37], [38], [39], [40].
An extension of the HeERO project, the HeERO2 project, was launched in 2013 [41]. At the same time, the CIP funded project Compass4D implemented three cooperative services in seven European cities [42]. A Spanish initiative, titled CIVICO, focused on the security of vehicle information, while the Austrian ECo-AT project aimed to create harmonized C-ITS applications [43], [44]. In 2014, seven European cities / logistics hubs joined the CO-GISTICS project, in order to implement C-ITS services for road safety and cargo security [45]. The SCOOP@F project was also a C-ITS pilot deployment project, as well as the Repsol Security Parking project, which contributed in the optimal use of parking places [46], [47]. Under the Beter Benutten (Optimising Use) programme, the Dutch government agreed in 2014 to support C-ITS national deployment [48].
Funded by the programme Horizon 2020, the projects PROSPECT, CIMEC and CODECS, were launched in 2015. The PROSPECT project aimed for the evolution of the first generation of automatic emergency braking (AEB) systems, while the projects CIMEC and CODECS constituted Coordination and Support Actions [49], [50], [51]. In the same year the XCYCLE project developed C-ITS technologies for cyclists, while two CEF funded projects, I_HeERO and NordicWay, constituted pre-deployment pilot activities for the implementation of C-ITS services [52], [53], [54]. At a national level, German, Dutch and Austrian road operators collaborated for a European-wide C-ITS implementation under the Cooperative ITS Corridor project [55]. The Netherlands introduced the DITCM Architecture project and the UK launched the A2 / M2 (London to Dover) Connected Vehicle Corridor project [56], [57]. During 2016 four C-ITS deployment projects were funded by CEF: CITRUS, SolC-ITS, InterCor and C-Roads [58], [59], [60], [61], [62]. EC DG MOVE funded the C-The Difference project, in order to upgrade the pilot sites of Bordeaux and Helmond, while the project SCOOP@F Part 2 examined the development of a hybrid 3G-4G / ITS G5 communication solution [63], [64].

2. THE COMPASS4D AND CO-GISTICS PROJECTS

The EU-funded Compass4D project (ended in December 2015) focused on three services, which increased drivers' safety and comfort by reducing the number and severity of road accidents, as well as by optimising the vehicle speed at intersections and by possibly avoiding queues and traffic jams. The three services, **Energy Efficient Intersection (EEI)**, **Road Hazard Warning (RHW)**, and **Red Light Violation Warning (RLVW)**, had also a positive impact on the local environment by enabling the reduction of CO2 emissions and fuel consumption for equipped vehicles. The services were implemented through a combination of established technologies and available pre-commercial equipment, such as Dedicated short-range communication (ITS-G5) and cellular networks (3G / LTE), following ETSI TC ITS standards. The Compass4D services were piloted during one year in seven cities, Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona and Vigo, while prior to the pilot operations, the implementation phase lasted more than one year and was a result of teamwork involving all consortium partners [65].

CO-GISTICS was the first European project fully dedicated to the deployment of C-ITS focused on logistics. CO-GISTICS services were deployed in seven European logistics hubs, Arad, Bordeaux, Bilbao, Frankfurt, Thessaloniki (Greece), Trieste and Vigo. The project officially ended on 30th June 2017 but will continue its activities to enable the deployment of C-ITS services. The partners will work together for three years on the installation and running of cooperative services on at least 315 vehicles (trucks and vans). CO-GISTICS deploys five services, Intelligent Truck Parking and Delivery Areas Management, Cargo Transport Optimisation, CO_2 Footprint Monitoring and Estimation, Priority and Speed Advice, Eco-Drive Support [66].

3. THE C-MOBILE PROJECT

The C-MobILE (Accelerating C-ITS Mobility Innovation and depLoyment in Europe) project, funded under Horizon 2020, envisions a fully safe & efficient road transport without casualties and serious injuries on European roads, in particular in complex urban areas and for Vulnerable Road Users (VRUs). C-MobILE aims for a congestion-free, sustainable and economically viable mobility, minimizing the environmental impact of road transport. Over a 42-month timeframe, the consortium C-MobILE will deploy services for specific mobility challenges in different settings / environments and for a range of use cases having a strong uptake potential, such as VRUs' safety at intersections, traffic light operation, eco-driving, traffic routing, goods delivery and parking [67].

C-MobILE will focus on easing the decision process of local authorities to invest in C-ITS, creating awareness of C-ITS solutions in real-life situations, reducing complexity for development and making C-ITS accessible for the general public to develop front-end services to enable low-cost and wide-scale deployment on smartphone and other commodity devices. A total of eight C-ITS equipped cities / regions are involved in C-MobILE, Barcelona, Bilbao, Bordeaux, Copenhagen, Newcastle, North Brabant Region, Thessaloniki and Vigo. The project will elevate existing research pilot sites to large-scale deployment locations of sustainable

services thanks to 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 is 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, as well as 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 [67].

3.1. Objectives and scope

To address the aforementioned challenges and vision, C-MobILE has eight objectives listed below [67]:

- ✓ Define a C-ITS framework in partnership with all key stakeholders for proposing robust deployment enabling solutions, including business cases, for the pilot sites as well as other cities and regions.
- ✓ Create a Strategic Research Agenda addressing key research and innovation areas to promote sustainable C-ITS deployments and lead towards automated transport in Europe.
- ✓ Assess the cumulative, real-life benefits of bundling C-ITS applications and integrating multiple transport modes in the C-ITS ecosystem.
- ✓ Demonstrate an open and secure large-scale deployment of C-ITS applications in complex urban environments interoperable across countries involving large groups of end-users.
- ✓ Provide an open deployment platform towards C-ITS sources by creating open access, secure software libraries and development platforms to support deployment of applications on commodity devices.
- ✓ Define an operational process for large-scale deployment of sustainable C-ITS services in Europe.
- ✓ Release testing methodologies to evaluate C-ITS architectures and the effectiveness of applications.
- ✓ Demonstrate the added value and economic viability by means of a comprehensive Cost-Benefit Analysis and impact assessment.

Regarding the scope of the project, it is described through certain initiatives, including: functioning partnerships of stakeholders, commitment of pilot sites, post-demonstration impact assessment, cost-benefit assessment, evaluation of C-ITS concepts and technologies for implementation, identification of the relevant technologies and processes, sustainable operation, support automated transport, services based on sharing in-vehicle and V2X data, including VRU, interoperability and standards, demonstrate and validate cross-modal integration, SMEs with proven experience, twinning with US, in particular on validation methodologies [67].

3.2. Overall approach and methodology

C-MobILE will demonstrate C-ITS solutions at large-scale in urban and extra-urban environments. This will be achieved by opening up existing ITS-enabled cities via a hybrid communication architecture (i.e. integrating current C-ITS technology with cellular technology) and by providing C-ITS services and applications in a seamless, uninterrupted cross-modal and cross-border way. The C-MobILE architecture will solve the common challenges of secure, private and reliable communication for C-ITS, provide a standardized mechanism for large-scale service delivery of C-ITS applications, as well as ensure compatibility between existing pilot sites and serve as baseline for uptake in new locations [67].

C-MobILE clusters applications into four thematic application 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 and enables integration of existing applications through a multi-variant optimisation of properties of the individual applications. The service bundles will be developed and provided in the form of open, modular and extendable wrap applications, which (by having the ability to interface with all single services) will bring together the complete suite of C-ITS services under one common user environment, with rich user experience features. The bundles will be able to operate either in an automated mode, by providing context, location and user-preferences based information and guidance to the end user as well as in a user-selected mode, where the end user selects the specific service or services relevant and useful for him / her. For each application, the required stakeholders, estimated implementation complexity, maturity level, user groups, and potential benefits will be assessed and analysed in detail, in order to ensure that all needs and requirements will be captured and accounted for. Based on this assessment, applications are combined into the following four bundles, sorted by core themes: urban efficiency, infrastructure-to-vehicle safety, traffic efficiency, and vehicle-to-vehicle safety [67].

Table 1: Overview of bundles and applications in C-MobILE.

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

C-MobILE will address interoperability issues by applying interoperability methodologies and standardization efforts. Applicability will be addressed by providing scalable functionalities for each use case in order to deploy a service in a large area. Besides, attention will also be paid to efforts for deployment, configuration and operation in order to have a comprehensive CBA of functionalities in different settings and complex environments. With these methodologies, the project targets at least TRL7 for all use cases, from which the most prominent (quick-win) application bundles will be identified by city-led business partnerships [67]. The overall approach of 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 are extensively validated on the technical aspects and user / societal impacts. The deployment process is defined, and it is identified how services are made sustainable through the functioning stakeholder partnerships. This leads to C-ITS deployment on the C-Mobile pilot sites, and replication to other cities by publishing deployment guidelines, etc. [67].

3.3. Pilot sites and users

C-MobILE extends upon existing C-ITS technologies and research results by leveraging on existing equipped pilots and C-ITS services available in a selection of cities in order to progress towards large-scale deployment and to set the basis for Europe-wide C-ITS deployment. In all the C-MobILE pilot sites, C-ITS equipment and services are currently in operation to some extent. The C-MobILE demonstration will focus on current urban challenges at specific urban and extra-urban locations, and specifically address the interaction with VRUs. On a small scale the extension towards automated driving is piloted. On each of the pilot sites a significant number of and variety of users will be involved, where the main upscaling is achieved though deployment on commodity devices such as smartphones [67].

Regarding the pilot site of Thessaloniki, bundles 2 and 3 are to going be deployed. The pilot phase includes C-ITS installations of 30 intersections, 10 km (inter-)urban roads, 10 km motorway, as well as user extension with 6500 additional cars and 300 additional pedestrians (600 existing taxis). Concerning bundle 2, the current infrastructure comprises of Compass 4D roadside (G5 ITS stations), in-vehicle and back-office infrastructure (installed at Ring Road, TMC and POMS), Bluetooth detectors network capturing traffic parameters & events, and FCD capturing traffic parameters & events, hence no update is needed. The existing service is the RHW, while the update for C-MobILE includes service extension also at CBD area and at urban-interurban gateways, implementation of Road works warning, Emergency vehicle warning, Signal violation warning, Pedestrian safety warning, bundling of safety related C-ITS services and provision of services to extended user base. Concerning bundle 3, an update of the current infrastructure is necessary, including interfaces development and integration of additional signal controlled intersections in C-ITS enabled TMC (urban-interurban gateways: city-airport route, approximately 10 additional kms and 10 additional intersections). The existing services are GLOSA, In-vehicle signage, Mode & trip time advice (advanced traveler information services-ATIS) and Probe vehicle data based ATIS. The C-MobILE update includes the improvement of the GLOSA service (incl. algorithms and UI), Green priority service, C-ITS for pedestrians, flexible infrastructures, bundling of related C-ITS services and provision of services to extended user base [67].

3.4. Progress beyond the State-of-Art and innovation

The C-MobILE proposal aims to contribute significantly towards the creation of new knowledge and operational process innovation and the expansion of the state-of-the-art in a number of areas. The project will develop agreed roadmaps and guidelines for self-sustaining coordinated and interoperable large-scale and real-life deployment of C-ITS framework leveraging on EU pilot site locations and allowing large user groups. The C-MobILE C-ITS architecture will contribute to the advancement of C-ITS deployment framework across Europe, while a method for integrating individual C-ITS services and applications under a bundled suite of applications, will be created. Aspects to be considered involve: user acceptance and partnerships of stakeholders in a true deployment, extra-urban environments focusing on seamless user interoperability and service continuity, safety and security aspects of open and large-scale C-ITS deployment [67].

User-centric approaches and multi-stakeholder involvement will be exploited to overcome the limitation due to the main focus of the C-ITS community being placed on solving purely technology driven barriers. Limitations and hesitations associated with uncertainties of users providing and sharing their own data will be investigated. New concepts and tools for improved overall performance and efficiency of the mobility system and business operation will be developed. Identification and definition of sustainable business models and plans will be proposed and agreed with stakeholders, developed based on addressing large user groups and the use of commodity devices such as smartphones. An open and interoperable deployment platform will be provided to back-end solutions of C-ITS framework, allowing new communities of (smartphone) app developers to provide services using secure libraries and development platforms. New front-end services will be made available (for smartphones and other commodity devices to the general public), so that C-ITS will hook-on large market solutions resulting in scaling the C-ITS application bundles [67].

C-MobILE objectives, concept and approach are associated with several innovative aspects. The project overcomes current isolated and fragmented efforts in C-ITS deployment, by addressing technical, business, and legal operations simultaneously and iteratively. It goes beyond today's C-ITS services offer' forms of provision by uniting applications. C-MobILE bridges also the gap among the stakeholders involved in the C-ITS domain by uniting them, in terms of collaboration in the business value chain for the support of interoperable C-ITS deployment. The project pioneers in geographically extended coverage of C-ITS services, by uniting geographical implementations. Existing however scattered pilot sites across Europe will be connected, including corridors and mixed road networks, paving the way for transferring the C-MobILE outputs to other regions and countries. C-MobILE adopts and extends commonly accepted methodological frameworks (e.g. FESTA and Amitran) for real-life assessment of C-ITS. A harmonized and integrated C-ITS deployment across Europe is pursued by C-ITS services' integration into the European Wide Service Platform (including standardization and certification), to ensure interoperable and secure operation and businesses. The project supports as well evidence-based decision making, by deriving implications of success criteria of stakeholders, deployment roadmaps and aforementioned innovations on decision making processes related to European C-ITS deployment policies. C-MobILE will create the state-of-the-art, future-proof C-ITS deployment platform, providing a reusable, shareable and open model of the architecture, based on OMG XMI standards [67].

4. CONCLUSIONS

The project C-MobILE aims to pave the way for the pan-European implementation of C-

ITS through the involvement of key-stakeholders at local, regional and European ecosystems, the development of a harmonized C-ITS architecture, the promotion of investments in C-ITS, and the development of commonly accepted assessment methods. The positive impact of the project can be summarized in: 1) improving the level of performance for the entire surface transport system, 2) demonstrating fully integrated C-ITS concepts in real-life, complex environments, promoting collaboration between multiple stakeholders (to deploy applications and facilitate the interoperable interactions across all elements of the transport system), 3) demonstrating the value added and economic viability of C-ITS services and solutions for users and other stakeholders, 4) estimating benefits regarding user acceptance, safety, resilience and security, and 5) developing validated guidelines for the large-scale deployment of operational and sustainable C-ITS services in Europe.

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