Cooperative and connected intelligent transport systems for sustainable European road transport

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Cooperative and Connected Intelligent Transport Systems for Sustainable European Road Transport

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Abstract

Intelligent Transport Systems (ITS) covers a wide range of products and solutions that deploy Information and Communication Technologies (ICT) aiming at improving traffic safety, transport efficiency, environmental efficiency, energy efficiency and driver comfort. The development and large-scale deployment of C-ITS (Cooperative ITS) will not only provide services for road users, but also substantially contribute to automated road transport. 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 research pilot sites for deployment of sustainable services that are supported by local authorities, and ensure interoperability and seamless availability of high-quality services for end users, that will be successful from a business perspective. The paper will present some preliminary results of C-MobILE, including recently developed business model for C-ITS deployment and an initial generic architecture, followed by some discussions.

Keywords: Intelligent Transport Systems; C-ITS; services; business model; architecture

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1. Introduction

Intelligent Transport Systems (ITS), based on Information and Communication Technologies (ICT), aiming at improving traffic safety, driver comfort, transport efficiency, and environmental and energy efficiency, have demonstrated high impacts on sustainable road transport (Lu (Ed.), 2016). The core technologies are sensor technology, communications, information processing and control technology.

Communication of vehicles with each other (V2V), with the infrastructure (V2I) and with vulnerable road users are expected to bring substantial benefits for European road transport (Lu & Blokpoel, 2017). These communication modes are summarised in the term V2X, vehicle to anything (relevant). Within C-ITS (Cooperative Intelligent Transport Systems), potential services are determined by the C-ITS Platform (2016) (See Table 1).

Table 1. C-ITS services (C-ITS Platform, 2016)

List of Day 1 services	List of Day 1'5 services Column B (*t*)
Hazardous location notifications:	Information on fuelling & charging stations for alternative fuel vehicles
Slow or stationary vehicle(s) & Traffic ahead warning	Vulnerable Road user protection
Road works warning	On street parking management & information
Weather conditions	Off street parking information
Emergency brake light	Park & Ride information
Emergency vehicle approaching	Connected & Cooperative navigation into and out of the city (1st and last mile, parking, route advice, coordinated traffic lights)
Other hazardous notifications	Traffic information & Smart routing
Signage applications:	
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	

The next section provides a literature review of related C-ITS development and deployment, followed by a brief introduction about the project C-MobILE (Accelerating C-ITS Mobility Innovation and depLoyment in Europe), which aims to stimulate large-scale, real-life and interoperable C-ITS deployments across Europe. Business model development method and preliminary results will be described. A generic architecture is initiated. Further innovation actions in C-ITS are proposed. Finally conclusions are drawn.

2. Literature Review of C-ITS Development and Deployment in Europe

C-ITS has been developed more than one decade (see Fig. 1). In 2005 the EC, under the FP6-IST funding scheme, launched three IPs (Integrated Projects): CVIS (Cooperative Vehicle Infrastructure Systems; focusing on the infrastructure side and traffic efficiency) (CVIS Consortium, 2005), SAFESPOT (Co-operative Systems for Road Safety "Smart Vehicles on Smart Roads"; focusing on the in-vehicle side and traffic safety) (SAFESPOT Consortium, 2005) and COOPERS (CO-OPerative SystEms for Intelligent Road Safety; focussing on the domain of the road opera-tor) (COOPERS Consortium, 2005), targeting cooperative systems. Germany launched the project Aktiv for enhancing traffic safety, including also the CoCarX research initiative (Aktiv, 2017).

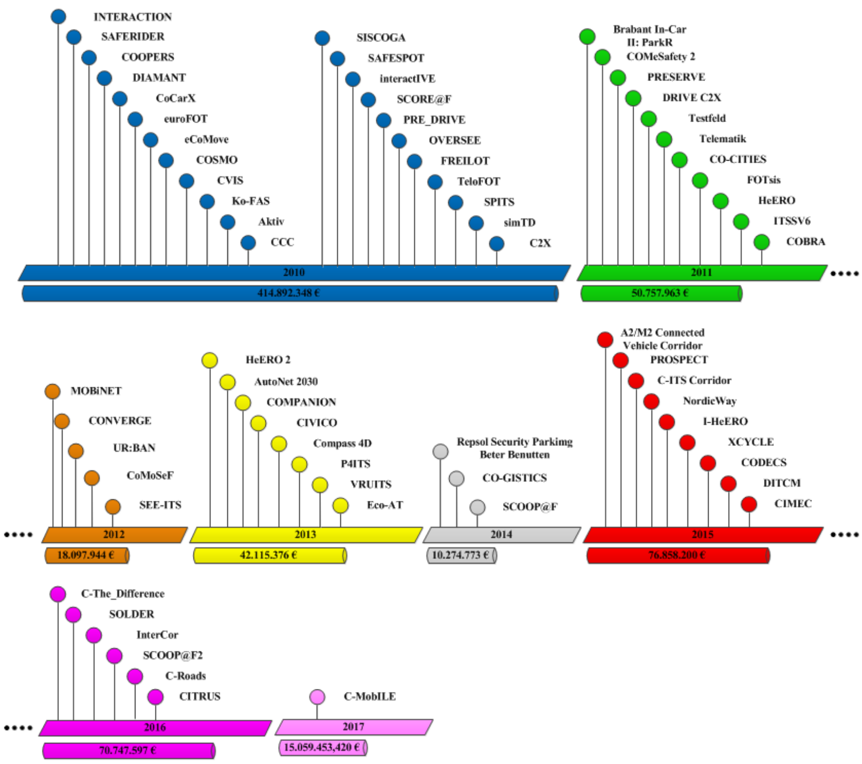

Fig. 1. An overview of C-ITS development and deployment projects in Europe (Mitsakis, et al, 2018)

During 2008, the projects SAFERIDER and TeleFOT were funded by EU under FP7 (Framework Programme). SAFERIDER provided ADAS and IVI systems in motorcycles, while TeleFOT conducted FOTs for IVS and aftermarket vehicle devices. 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. In 2009 the EC launched the FREILOT project, which developed C-ITS services for road goods transport. At a national level, Germany as well as the Netherlands, launched two C-ITS deployment projects, Ko-FAS and SPITS respectively. The projects SISCOGA, eCoMove, interactIVe, OVERSEE and COSMO were launched in 2010, aiming to foster energy efficiency by developing various C-ITS services. 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. 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. In the field of FOTs, EC launched the FOTsis project and the ITSSv6 project. Another three 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. (EC CORDIS, 2017)

In 2012, the projects MOBiNET (MOBiNET Consortium, 2002) and SEE-ITS (Mitsakis, et al, 2015) targeted respectively in deploying an open platform for Europe-wide mobility services and stimulating cooperation in South East Europe. Regarding C-ITS deployment activities at a national level, Germany launched the projects CONVERGE and UR:BAN, while Finland introduced the CoMoSeF project. 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 (EC CORDIS, 2017). An extension of the HeERO project, the HeERO2 project was launched in 2013. At the same time the CIP funded project Compass4D implemented three cooperative services in seven European cities. 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. 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. 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. Under the Beter Benutten ("Optimising Use" in English) programme, the Dutch government agreed in 2014 to support C-ITS national deployment. (EC CORDIS, 2017)

Under Horizon 2020, the projects PROSPECT, CIMEC and CODECS were launched in 2015 (EC CORDIS, 2017). The PROSPECT project aimed to the evolution of the first generation of AEB systems, while the projects CIMEC and CODECS constituted Coordination and Support Actions. 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. At a national level, German, Dutch and Austrian road operators collaborated for a European-wide C-ITS implementation under the Cooperative ITS Corridor project. The Netherlands introduced the DITCM Architecture project and the UK launched the A2/ M2 Connected Vehicle Corridor project (Sambeek, et al., 2015; Amsterdam Group, 2016). During 2016 four C-ITS deployment projects were funded by CEF: CITRUS, SolC-ITS, InterCor and C-Roads. 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. At last, the ongoing C-MobILE project (2017-2020), funded under H2020, focuses on the deployment of C-ITS services for specific mobility challenges in eight C-ITS equipped cities/ regions, in particular in complex urban areas and for VRUs (EC CORDIS, 2017).

3. Objectives and Approach of C-MobILE

The project C-MobILE 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. Combined C-ITS services (so-called 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). (C-MobILE Consortium, 2017)

The C-MobILE approach is illustrated in Fig. 2. 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. (C-MobILE Consortium, 2017)

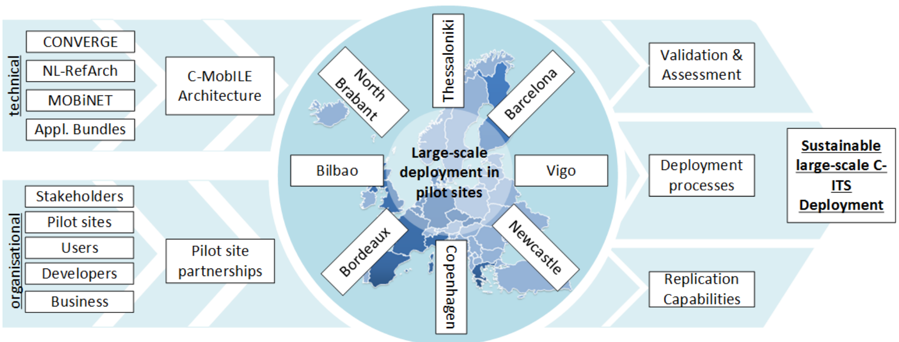

Fig. 2. C-MobILE approach (C-MobILE Consortium, 2017)

4. Service-Dominant Business Models for Mobility Solutions

Currently, many developments are taking place in the field of mobility, transportation, and traffic management. Many of these initiatives, however, have hard time finding their way to practical, large-scale exploitation. One of the reasons behind this is the limited view on business models and market considerations. Many of these developments have a technology-push character, where things are developed inside-out, with a focus on the concepts and technology in the mobility transportation from the very start, and with limited attention for actual business deployment at the end. This situation is made worse by the fact that complex mobility scenarios involve a multitude of stakeholders, each of which has its own business interests.

Recent projects on the design of agile, *service-dominant business models* in multi-stakeholder contexts in the mobility landscape has shown that the application of such a business design approach offers a constructive, collaborative way to develop blueprints for the definition of cases of concrete added value of mobility technologies and new forms of business collaboration to realize these cases of added value (Grefen et al. 2015; Grefen, Turetken, and Razavian 2016; Sambeek et al. 2015; Traganos et al. 2015).

A service-dominant business model identifies the added value of the service to the customer or user, functions and capabilities required by each party (organizations, institutions, companies, customers, etc.) participating in the model, as well as the expected costs and benefits. The business models (BMs) for a service (or a coherent collection of services) provide a solid basis for the requirements for the solutions and cost & benefit analysis for such solutions.

As a part of the tasks to be performed in the C-MobILE project, we initiated the tasks for designing blueprint business models (BMs) for the C-ITS services or service bundles in collaboration with the stakeholders in local sites. The approach followed for Business Model Design is based on the BASE/X framework (Grefen 2015) that has been successfully used in engineering business in several domains - particularly in mobility and traffic management (Grefen et al. 2015, 2016; Sambeek et al. 2015; Traganos et al. 2015). The conceptual tool that will be used as a guiding reference for business model design is the Service-Dominant Business Model Radar (SDBM/R), which is an integral component of the BASE/X framework (Turetken and Grefen 2017).

4.1. Service Dominant Business Model Radar (SDBM/R)

SDBM/R has a *network-centric* design at its core, allowing the composition of service design in multi-party business networks. It defines how the actors in the business ecosystem participate in value co-creation and what the cost–benefits distribution is (Turetken and Grefen 2017). Fig. 3 presents the elements of the SDBM/R. The *co-created value-in-use* constitutes the central point in SDBM/R. Following service-dominant thinking, it represents the value of a solution to a customer.

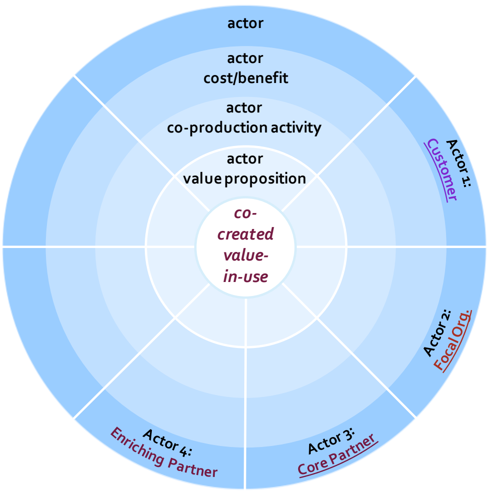

Fig. 3. Service Dominant Business Model Radar (SDBM/R) template

The first concentric layer framing the value-in-use contains the *actor value propositions*, which represent the part of the central value-in-use contributed by a single actor. The *co-production activity* defines the activities that each actor performs in the business for achieving the co-creation of value, i.e. its actor value proposition. The effects of this activity are observable by the customer. The third frame –*actor cost/benefits* defines the financial and non-financial expenses/gains of the co-creation actors. Finally, each "pie slice" of the radar represents a *co-creation actor*, including the focal organization, core and enriching partners, and the customer.

We put the labels of the actors in the fourth frame. The *focal organization* is often the party that initiate the setup of the business model, and participates actively in the solution. The *customer* is always one of the parties contributing to the production of the value-in-use. A *core partner* contributes actively to the essentials of the solution, while an *enriching partner* enhances solution’s added value-in-use. SDBM/R accommodates an arbitrary number of actors, suiting the network-centric character of service-dominant business. The provisioning of mobility solutions can be analysed from a service-dominant perspective and typically involves many actors (either direct or indirect) in multi-sided business models. Next section describes an initial set of business models resulted from the workshops organized with several stakeholders in the mobility domain.

4.2. Service Dominant Business Models in the C-MobILE Context

We have conducted four workshops aiming at collaboratively designing business models in the mobility domain, which have been supported through the SDBM/R. These workshops brought together several stakeholders in C-MobILE pilot sites in Helmond/Eindhoven (The Netherlands), Thessaloniki (Greece), Copenhagen (Denmark), and Bordeaux (France) including public authorities, technology/service providers, municipalities, and road authorities, as well as representatives of mobility service users (such as drivers and vulnerable road users – VRUs, represented by pedestrian and cyclist federations).

In the following sub-sections, we briefly describe a number of business models which were emerged from these business model workshops. The sub-section 4.2.6 provides a more detailed description of a business model together with an SDBM/R and associated stakeholder roles.

4.2.1. Hassle free concert experience (by mode and trip time advice)

A hassle-free concert experience is offered through mode and trip time advice to *event visitors* which opt to switch visiting an event by car for visiting by public transport. A *service provider* provides mode and trip time advice to users and provides a platform through which public transport tickets can be bought at reduced rates by event visitors. As event visitors are stimulated to take and arrive by public transport, hassle with traffic and parking at the event location is avoided. The business model is completed by incorporating *the public transport operator* (responsible for relocating event visitors), and financed through including either *retailers, municipality* or *event provider*.

4.2.2. Reliable arrival times (by mode and trip time advice)

In this business model, *truck companies* can enjoy more reliable arrival times through mode and trip time advice. A *service provider* integrates real-time truck (location) data, traffic data and retailer data to provide optimized advice on route and trip time. Accordingly, both the *truck driver* and *retailer* can benefit from more reliable arrival times. The business model is completed by incorporating the *traffic operator* and *ICT operator* (responsible for managing IT infrastructure to enable the service).

4.2.3. Green and comfortable commuting (by urban parking availability)

Green and comfortable commuting is offered in this business model to *the municipality* by providing advice on parking availability in the (inner) city. *The service provider* collects data on the *commuter by car’s* location and destination, as well as data on parking space availability. Consequently, an optimized advice is offered to commuters by car on where to park (through in-vehicle signage), as well as how to proceed towards the desired destination. This may even include compensations for transit tickets to stimulate using the service. In turn, the *municipality* will benefit from its traffic users commuting in a green and comfortable manner. The business model is completed through incorporating the *public transport operator* and *road operator*, and can be financed through including *employers* or stimulated through the *municipality*.

4.2.4. Safe travelling experience (by warning signage)

In this business model, *car drivers* can benefit from a *safer travelling experience* through in-vehicle warning signage. *Car drivers* are offered with a software application by a *service provider* which collects data on the *car driver's* behaviour as well as the behaviour of other traffic users (specifically *VRUs*). The service integrates both streams of data and consequently offers the car driver optimized driving advice or a warning signal to adapt the current driving behaviour in case the car driver is likely to collide with other traffic users. As such, the car driver can benefit from a safer travelling experience. The business model is completed through incorporating *the traffic operator* and *software operator*, and can be financed through support of the *municipality* or *insurance companies*.

4.2.5. Optimized driving experience (by Green Light Optimized Speed Advisory)

This business model aims to provide *car drivers* an optimized driving experience through real-time optimized speed advice. *Service provider* offer a software application (or on-board unit) to *car drivers* which can track their speed and location. Through integrating user and traffic data, the *service provider* can offer real-time advice with regards to the (expected) state of upcoming traffic lights, allowing *car drivers* to alter their speed accordingly. The business model is completed by a *sponsor*, which ensures the financial feasibility of the model, as well as *a road operator* and *data provider*, which take care of both streams of data.

4.2.6. Comfortable cycling / walking (through traffic light prioritization for VRUs)

In this business model, *cyclists or pedestrians* are offered a more comfortable cycling / walking experience through traffic light prioritisation. Cyclists or pedestrians are equipped with a smartphone application (offered by a *service provider*) which can interact with nearby traffic lights. Based on the behaviour of the user, green light time is either extended or time to green is reduced, allowing cyclists or pedestrians to enjoy a more comfortable experience. The business model is completed by the *road operator*, and financed through including *retailers* and/or *employers*.In the following, we provide an elaborated description of this business model for cyclists. For this model, an employer (an organization, or a business/industrial zone) endorses cycling as the choice of commuting for its employees. This is with the aim to lessen the traffic around and within its premises, and reduce the need for parking spaces for cars. To foster this, a Service Provider offers a priority crossing for cyclists via a smartphone application. The Provider delivers software activation codes to the Employer, which distributes to its Employees that commute by bike. The operation of the service can optionally be activated only during certain time periods (e.g. rush hours).

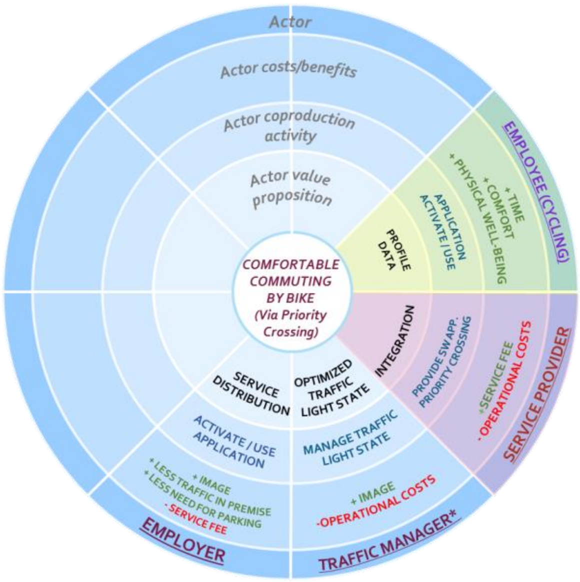

Fig. 4. Business model radar: Comfortable commuting by bike (via priority crossing)

Fig. 4 depicts the essential components of the blueprint business model for this scenario using the Service-Dominant Business Model Radar (SDBM/R). The central value offered by the network of parties is the comfortable commuting through the use of priority crossings for bikes. The comfort implies that the cyclist can maintain a regular speed or flow whilst cycling and is either interrupted less frequently at intersections or can more quickly continue his or her journey after a stop. The employee (cyclist) uses the code to activate the application, which runs in the background and interacts with traffic lights (and associated systems) at intersections. As such, no interference of the cyclist is needed. Once the cyclist -with this application running in his/her smart phone, approaches to the traffic light, two scenarios can occur. In case of a red light, increased priority is given to the VRU by activating the green light quickly and allowing cyclist to continue with reduced waiting time. In case of a green light, the duration is extended to support the flow.

The *employee* (cyclist) uses the code to activate the application, which runs in the background and interacts with traffic lights (and associated systems at intersections). The application tracks the location and direction of the employee and integrates this data with traffic light state information in order to provide traffic light prioritisation to cyclists. This service can be customized or adapted based on the user's characteristics or profile (i.e., handicapped or elderly user). The *service provider* provides traffic light prioritisation to its users. The service depends on integrating floating cyclist data with traffic light state data in order to provide priority to approaching cyclists at a specific traffic light. This data is consequently forwarded to the traffic manager. Therefore, the value proposition of the service provider is to *integrate* both sources of data in order to provide the service to the employee. The *traffic manager* (or in case integrated, *the municipality*) is responsible managing the traffic lights and providing optimized traffic light states for cyclists using the service application. Based on the integrated data received from the service provider, the traffic manager warrants either priority to additional crossing time at traffic lights (i.e. either faster time to green or extended green). The *employer* is the party that wishes to stimulate its employees to commute by bike. The role of the employer is to distribute the service through buying and offering the codes to its employees.

There are various business opportunities – particularly for the service provider, with the profile data obtained from VRUs. For instance, the profile and regular routing information of the cyclists can be used to provide customized promotions for the commuters. Retailers might be interested in advertising products or services through the application if the data profile shows that cyclists take a route on which the retailer is located or in the vicinity. The 'priority crossings for VRUs' service can be used also for promoting safety for elderly and/or handicapped pedestrians in urban areas. For instance, the municipalities can use the service to provide more comfortable and safer walking experience for its elderly and handicapped citizens. The service can be used to extend the green-light duration in crossings through the use of the software application. Following a similar scenario in the business model depicted in Fig. 4, the employer can be replaced by municipalities, insurance companies, or non-profit organizations aiming at improving the quality of life for elderly and handicapped.

4.3. Future Steps for the Service Dominant Business Models

In addition to the set of workshops that have been conducted, there are four workshops to be organized in the remaining C-Mobile pilot sites (namely, Barcelona, Vigo, Bilbao and Newcastle). After the definitions of the initial versions of these business models, in the upcoming phases of the project the models will be operationalized in pilot sites with concrete business plans and implemented. Based on the lessons learned and the data originating from the implementation of the models, the initial business models will be improved and finalized, and published as a repository of blueprint business models that can be adapted and implemented in large-scale in other European cities.

5. Generic Architecture of C-ITS Deployment

We propose an generic architecture based on the architectures developed in MOBiNET (MOBiNET Consortium, 2012) and CONVERGE (CONVERGE Consortium, 2012). 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 architecture is proposed (see Fig. 5). 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.

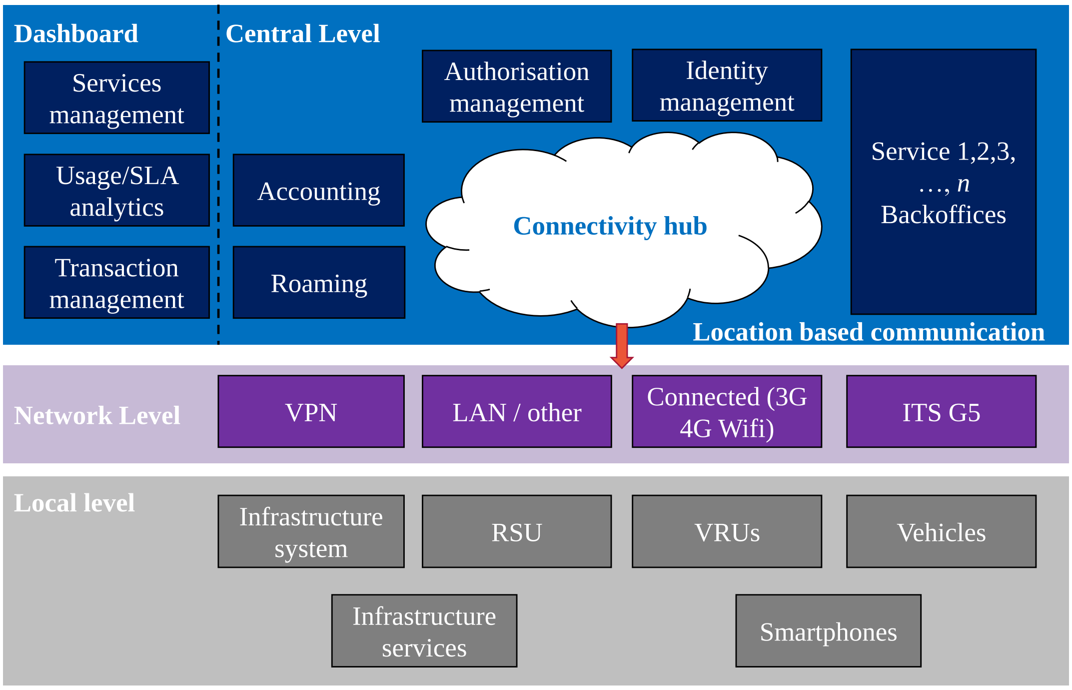

Fig. 5. An initial generic architecture of C-MobILE

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.

6. Conclusion

C-ITS (Cooperative Intelligent Transport Systems) implementations will enhance road transport safety, traffic and energy efficiency and environmental friendliness. All road users (including vehicles and VRUs - Vulnerable Road Users) will get benefits through various C-ITS services. In addition, large-scale and interoperable C-ITS deployment will pave the way for future automated road transport.

C-MobILE will stimulate the process of C-ITS deployments across Europe. An appropriate approach for business model development has been carefully selected. The implementation of the approach was very successful. Business model for various services and combined C-ITS services will be further developed and analysed. The generic architecture will be further developed to reach the objectives of large-scale and interoperable C-ITS deployment. 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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