Cooperative ITS Messages for Green Mobility:

An Overview from the eCoMove Project

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Abstract

Energy consumption reduction is key factor for sustainable mobility. This paper presents the design and specification of eCoMessages as a key technology component of the eCoMove project. These messages enhance existing protocols for vehicle-to-vehicle and vehicle-to-infrastructure communications, which were primarily designed for road safety applications. The ecoMessages enable a wide range of applications for ecoDriving and ecoTraffic management and Control, while taking into account requirements from safety applications. The use of the ecoMessages is described in the context of two Green Mobility use cases, i.e. emission-based intersection priority and truck platooning on highways

Keywords:

ECOLOGY, COOPERATIVE SYSTEMS, ECO-DRIVING, ECO-TRAFFIC, V2X

Introduction

Today's road transport contributes significantly to CO_2 emissions across the world. As road traffic still grows, the emissions are expected to increase in the next year. It grows despite the efforts to reduce the fuel consumption of vehicles, introduce advanced traffic management systems and raise awareness of drivers for eco-friendly vehicles and behaviour. For the mitigation of climate change, ambitious goals for a cleaner and more efficient road transport are set in governmental policies and long-term plans. The goals can only be achieved by a holistic approach and combination of measures.

Cooperative Intelligent Transport Systems (ITS) have a great potential to reduce fuel consumption. Being based on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, cooperative ITS enables drivers to utilize vehicles and roads in an eco-friendly manner and facilitates a variety of smart solutions for eco-specific traffic management and control. Communication-based eco-driving support includes measures for optimized vehicle routing based on static and dynamic data, driving assistance and post-trip driving analysis as well as logistics for freight transport. Eco-traffic management and control covers green wave for traffic lights, route distribution to mitigate congestion, motorway management and eco-traveller support. These applications can rely on existing communication technologies and protocols, but they require a specific type of messages and protocols that are referred to as eCoMessages.

Existing solutions for green mobility have shortcomings. Proprietary solutions [8-9] for information exchange, being introduced in the last years, are closed systems. This limits the proliferation of applications. Standardized messages and protocols, like those developed by ETSI TC ITS [4-5] and CEN TC 278, are primarily for road safety. Messages, generated based on preventive or reactive principles, allow road users to identify or been informed of potential dangerous situations, such as red light violation or black spots indication. Certainly, this message exchange could also be used for road traffic management, but applications for green mobility require richer information content.

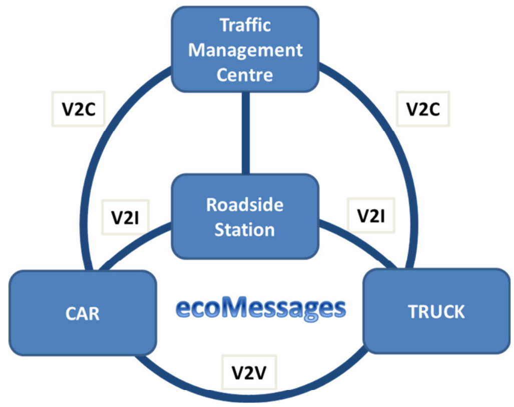

Figure 1 eCoMessages in the System Architecture
(v: vehicle, i: infrastructure, c: center station)

The three years project eCoMove [1], supported by the European Commission in the 7th Framework Programme, was started in 2010 to develop eco-aware system and related technologies. It targets at a reduction of fuel consumption by 20% and therefore CO2 emissions. Project partners include car makers, automotive suppliers, ITS solution and technology providers as well as research institutes. The project develops tests and evaluates an integrated solution for road transport energy efficiency to help drivers, freight and road operators to reduce fuel consumption and to manage road traffic in an energy-efficient way.

The present paper focuses on the result of the design of the eCoMessages as a key technology of the eCoMove system. They are used to exchange eco-related information by V2V or V2I communication among the core elements of the eCoMove system, composed of passenger cars, trucks, roadside stations and traffic management centres (Figure 1). The next sections present 1) the requirements of eCoApplication; 2) details of ecoMessages design; 3) Protocol considerations; 4) description of scenarios using ad hoc networking with GeoNetworking/BTP; 5) deployment aspects; 6) developed bundles in the eCoMove project and related aspects under discussion in ETSI.

Application Requirements and Sample eCo-Applications

The design of eCoMessages is based on the following main principles: 1) extend the current

ETSI specification; 2) allow interoperability with previous EU projects 3) implement requirements from eCoMove applications. The eCoMove applications, such as *ecoApproachAdvice*, *ecoRouteAdvice*, *ecoParkAdvice*, *ecoDrivingSupport*, *ecoDriverCoaching* and *ecoTolling* operate in different environment, more specifically urban, interurban and highway. The applications require an adequate support for location referencing and for two further key features: *ecoStrategy* and *ecoSituation*. The former allows building an overview of the emission level at network level, while the latter provides to application the environment where the vehicle is moving, including the traffic signal state, other vehicles in the same path or an indication of the behaviour of preceding vehicles. The messages shall allow infrastructure and other vehicles to: (a) build a representation of the road traffic in the vicinity; (b) inform about energy consumption parameters of the vehicle; (c) describe segments or intersections road geometry; (d) convey speed or time advice at lane or road level; (e) provide information on traffic signal timing; (f) enable the exchange of TPEG messages; (g) provide present, past and future position trajectories of vehicles; (h) publish service availability to vehicles or to the infrastructure.

Let us consider an signalled intersection. Most advanced systems adopt adaptive traffic signal control solutions. These systems rely on traffic data either via fixed infrastructure measurement systems or by means of proprietary protocols with dedicated vehicles. Messages like *CAM* [4] already include some vehicle information that can be used for intersection control strategies. Including emission and energy requirement in the message facilitates selective prioritization of vehicles based on vehicle's emission and energy usage characteristics. Furthermore, vehicles can receive speed advice while approaching the intersection. Truck transport is an important part of commercial transport.

Trucks have a considerable effect on emissions and energy consumption. In a highway scenario trucks could form platoons to allow for reduction of emissions. Nearby vehicles shall also collaborate by reducing the impact of their driving behaviour on the truck platoon, avoiding unnecessary reduction of speed. The exchange of acceleration and emission information enables cooperative platooning applications and allows nearby vehicles to reduce their interference on truck platoons.

Description of eCoMessages

Message Architecture

eCoMove is a European project with 32 partners; the majority of partners are directly involved in the development or integration efforts of the project. The interoperability, in particular with other European initiatives, is key requirement. The ecoMessages share a common header and are based on the structure of the Cooperative Awareness Message (CAM) and Distributed Environmental Notification Message (DENM) standards developed by ETSI TC ITS [4-5]. They use the ASN.1 specification for flexible and proven interoperability. To achieve further interoperability of information content, the eCoMessages refer to SAE J2735

[10] specification and CVIS API definition [11]. This allows continuity from previous projects, compatibility with ETSI TC ITS standard and functional compatibility with other on-going projects.

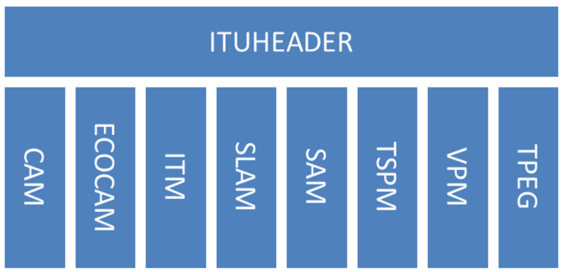

Figure 2 Message Architecture

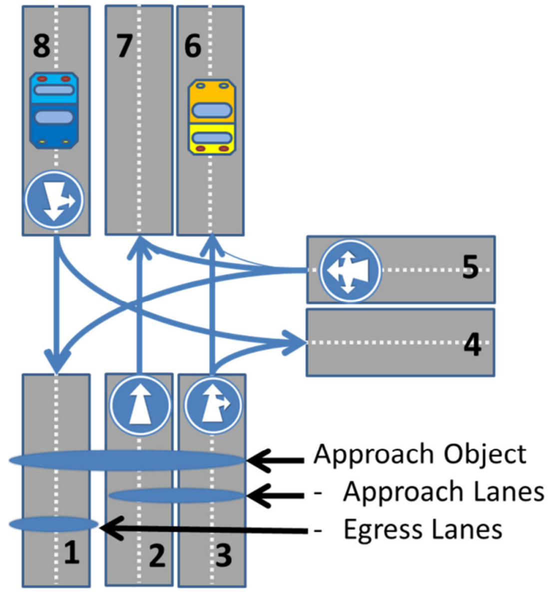

Figure 3 ITM example layout

Location Reference in eCoMove

Location reference is critical in ITS application, since information is strongly linked to the underlying road infrastructure. Location Reference technologies range from geographical coordinate to complex map based solution. Agora-C and OpenLR represent the more advanced version of "on-the-fly" location reference that avoids pre-coded tables. The location reference, applied in the eCoMove project, is based on geographical coordinates in the form of points, traces and composition of traces. Proposal for extension of existing protocol with Agora-C and OpenLR was documented in the eCoMove project report [2].

Intersection Topology Message

In urban environments, the major interaction among vehicles and infrastructure happens at road intersections. When infrastructure communicates information to vehicles and vice-versa or when vehicles exchange information at the intersection, it is necessary this information refers to a common representation of the intersection. For this reason the Intersection Topology Message (ITM) has been defined. ITM represents the intersection from both topological view, i.e. the connection among lanes, and geometrically, using geographical coordinates that mark the centreline lanes and other physical features. ITM contains also static information as maximum speed limit, turning restriction, lane width, lane use, etc. Typical messages using ITM are traffic signal phases and speed and time advice. ITM are derived from the SAE 2735 MAP message.

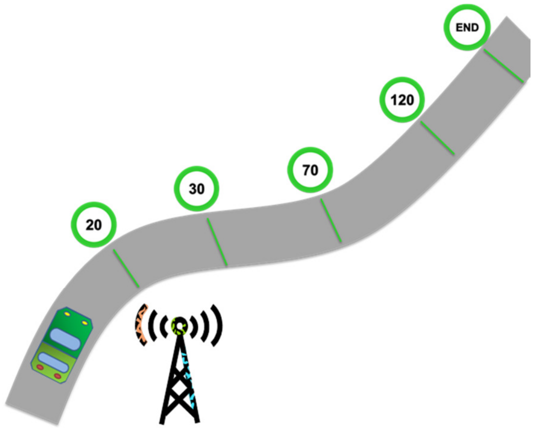

Figure 4 graphical representation of the SLAM

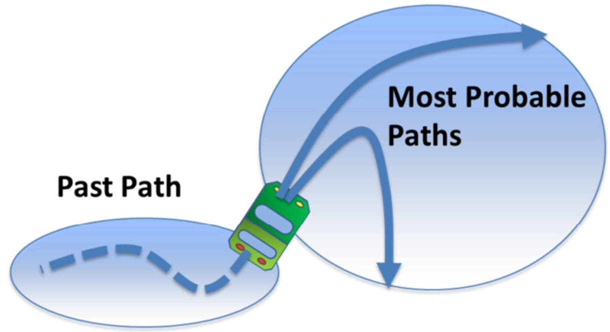

Figure 5 graphical representation of the VPM

Speed Lane Advice Message

Speed and Lane Advice Message (SLAM) allows the infrastructure to give direct driving behaviour advice to the drivers. Selecting the proper communication method, i.e. either broadcast or unicast to a specific vehicle, the message conveys either: 1) a speed, 2) a time or 3) a lane advice or a combination of the three. The message allows splitting the advice in multiple consecutive section of the same path to provide a speed/time profile over distance. Lane advice is designed for situations where the vehicle may benefit from using an optimal lane, either for turning or for road tolling.

Signal Phase Definition Message

Vehicle approaching an intersection may modify the speed in order to match traffic signal phase, but also to detect red violation from other vehicles. For these reasons the Signal Phase Definition Message (SPDM) has been defined. It follows a similar structure and information content as specified in SAE J2735 SPAT for interoperability.

Vehicle Path Message

Vehicle Path Message (VPM) allows a vehicle to communicate its past and most probable future paths. The most probable path (MPP) is a list of paths the vehicle can drive and their associated probability and destination. The next destination is only an intermediate step of the full trip of the vehicle. The information contained in the VPM is used by the cooperative horizon application to gather the information which is relevant to the vehicle. For example this information is used to detect possible collisions with nearby vehicles. Future paths are encoded using linear locations and apply, as described previously, geometrical coordinates. ETSI ITS WG1 is currently working to add past path information in the CAM to align with SAE J2735 BSM.

ecoCAM

CAM message is designed to convey information related to safety, for example to collision avoidance. ecoCAM is the extension of the message in order to contain also information related to the emission and consumption model of the vehicle. The specification of the ecoCAM is based on results of European projects on vehicular emission modelling and includes information on vehicle physical characteristics, vehicular emission class, fuel type, loading status and vehicular energy efficiency. The information on emission can be used by cooperative energy minimization application especially when associated with truck transport.

eCoMessage Protocol Consideration

In the ISO Open Systems Interconnection (OSI) model, the eCoMessages are layer 7 (application layer) protocols. According to the ISO and ETSI communications architecture for ITS, eCoMessages are messages at the *facility layer*. This implies that they that can serve multiple applications because they are not bound to a single application logic. By design, the eCoMessage protocols are independent of the transport, network and access layers. While they could theoretically be transported by any protocol stack and access technology, 3G/4G cellular and short-range wireless technologies (IEEE 802.11p/ITS-G5, aka DSRC) with ad hoc networking represent the most common application scenarios.

In the eCoMove project, eCoMessages are sent over both 3G UMTS and ETSI ITS-G5. For cellular-based communications, the eCoMessages are transported over IPv6, with TCP or UDP as the transport protocol. Since IPv6 connectivity for cellular networks is not fully available yet, IPv6 datagrams are transmitted via VPN tunnels over the public IPv4 Internet and the cellular network. The VPN solution for IPv6 over IPv4 tunnelling requires a VPN client in the vehicles and a VPN server. The VPN server is hosted by a back-end service centre that connects the vehicles with the service providers as well as with the public IPv6 Internet. For ad hoc communication with IEEE 802.11p/ETSI ITS-G5, the eCoMessages are transported by BTP and transmitted on a pre-defined service channel of ITS-G5. GeoNetworking is envisaged as specified in ETSI TC ITS standards.

Ad Hoc Networking with GeoNetworking/BTP

Ad hoc networking enables direct and rapid information exchange among vehicles. It complements the cellular network in areas where the cellular coverage is limited or short in available resources. However, when IEEE 802.11p/ETSI ITS G5 operates in the 5GHz frequency band, the communication range is limited to typically 500 meters or less depending on the environment. In order to extend the communication range, multi-hop communication can be considered, where vehicles or roadside stations relay messages and forward them to the destination.

A particular approach for multi-hop communication is GeoNetworking, a routing protocol for ad hoc communication over short range communication media, such as IEEE 802.11p/ETSI ITS G5. GeoNetworking is standardized by ETSI TC ITS (EN 302 636 standard series) [7]. GeoNetworking is a routing protocol that utilizes geographic positions to forward packets on the fly, without maintaining routes as other ad hoc routing protocols. It facilitates geographical addressing, e.g. a packet can be sent to all vehicles in a geographical area.

In order to assess the value of GeoNetworking in the context of ecoMessages, let us consider a platoon of tracks that exchange information to coordinate their movement. When single hop communication would be used, every vehicle processes the received messages and decides to forward or not to nearby vehicles. With GeoNetworking, the source of the GeoNetworking packet sets as destination a relative geographic area around its ego-position that covers all vehicles belonging to the platoon. So the application is responsible to build up the platoon, but not to manage the message exchange. The advantage in this case refers more on a ready to use feature and reduce development and interoperability problems. Another example scenario is speed advice: with single hop communication, the communication range can be as small as 150 meters (in city environments with signal blocking buildings and multi-path propagation). At a speed of about 50km/h, this communication range results in 10s time advance of the speed advice. With GeoNetworking, the time advance and range can be extended to the actual multi-hop communication coverage.

Deployment Aspects

Standardized messages and protocols enable the interoperability of applications. Correct interpretation and correct creation of the messages are important aspects for the real deployment of the applications. ETSI arranges Plugtests™ to ensure that the protocols and messages are implemented and interpreted correctly. The actual deployment of applications is affected by the correct representation of the road infrastructure and interfaces to the roadside infrastructure. This implies that verification of message format and content is necessary at the location of deployment. ITM describes the road intersection and needs to be updated when the underlying road infrastructure is modified, including any change in the traffic rules. Systems that use ITM shall be updated accordingly, implying the existence of an organizational structure that takes care of this process. SLAM covers different scenarios, such as lane advice for road tolling or speed advice along a road segment. The correct location of the advice and the relative distance in space and time of the vehicle is crucial for proper application function, putting requirement on the accuracy of location reference and ITM.

Developed Bundles and Standardization Activities

All messages are defined as ASN.1 modules following the conventions from ETSI TC ITS. A Java API is defined that hides implementation details and enables applications to access all data in natural units while ASN.1 encoding details are hidden. The design patterns of the API allows any application to construct and send messages and any application may listen to an incoming messages. NEC and Q-Free have implemented the messages in Java running in the OSGi framework in the eCoMove project [3]. Each implementation may add security features that enable more control of access to API.

In addition to the API and message processing bundles, tools exist for verification of the message processing bundles and message content. The flexible API allows generic message and replay tools to be made without any special adaptations of the messaging bundles. This tool enables system integrators and developers to make test drives in the field and record all ecoMessages to a file, which can be later transparently replayed to the application.

ETSI TC ITS in cooperation with ISO TC 278 is currently in charge of the specification of relevant standard to support the deployment of cooperative V2V and V2I applications in Europe. Activities are developed in coordination with U.S. in HTG2, in order to achieve compatibility at least at functional level. ETSI TC ITS includes activities in application requirement specification, protocol specification, networking and security specification. ETSI security specifications are based on IEEE 1609.2 specification; however a number of security topics are not standardized, partially because of different deployment models and different legislation. The U.S. networking and transport protocols are more optimized for broadcast communications patterns and less suitable for multi-hop communication than the European protocols. This may create challenges for deploying applications globally.

Conclusions

This paper describes the design process and results of the specification of cooperative eco-friendly application communication protocol and messages, carried out during the eCoMove European project. The paper presents the content of the messages, two example applications and a general overview of requirements for eCoMessages design. eCoMessages represent a key technology for more energy aware mobility.

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