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# Experimental evaluation of CAM and DENM messaging services in vehicular communications

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ABSTRACT

The Cooperative Awareness Basic Service and Decentralized Environmental Notification Basic Service have been standardized by the *European Telecommunications Standards Institute* (ETSI) to support vehicular safety and traffic efficiency applications needing continuous status information about surrounding vehicles and asynchronous notification of events, respectively. These standard specifications detail not only the packet formats for both the *Cooperative Awareness Message* (CAM) and *Decentralized Environmental Notification Message* (DENM), but also the general message dissemination rules. These basic services, also known as *facilities*, have been developed as part of a set of standards in which both ISO and ETSI describe the Reference Communication Architecture for future *Intelligent Transportation Systems* (ITS). By using a communications stack that instantiates this reference architecture, this paper puts in practice the usage of both facilities in a real vehicular scenario. This research work details implementation decisions and evaluates the performance of CAM and DENM facilities through a experimental testbed deployed in a semi-urban environment that uses IEEE 802.11p (ETSI G5-compliant), which is a WiFi-like communication technology conceived for vehicular communications. On the one hand, this validation considers the development of two ITS applications using CAM and DENM functionalities for tracking vehicles and disseminating traffic incidences. In this case, CAM and DENM have demonstrated to be able to offer all the necessary functionality for the study case. On the other hand, both facilities have been also validated in a extensive testing campaign in order to analyze the influence in CAM and DENM performance of aspects such as vehicle speed, signal quality or message dissemination rules. In these tests, the line of sight, equipment installation point and hardware capabilities, have been found as key variables in the network performance, while the vehicle speed has implied a slight impact.



## 1. Introduction

Cooperative applications in vehicular scenarios are becoming essential for the future connected vehicle within the ITS (Intelligent Transportation Systems) research field. They are supposed to decrease road fatalities, improve the capacity of roads, diminish the carbon footprint of road transport and enhance the user experience during travels. Although there are

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many vehicular applications envisioned for the short, medium and long term, these can be categorized in the next groups (Khaled et al., 2009; European Telecommunications Standards Institute, 2009b):

- *Safety*. These kind of applications are intended to reduce accidents and safeguard vehicle occupants and pedestrians lives. Some examples are collision avoidance, accident notification or emergency vehicle approaching.
- *Traffic efficiency*. In this group there are applications that improve the road network capacity and reduce the travel time. Some examples are variable speed limit, dynamic management of road intersections or congestion detection and mitigation.
- *Infotainment*. Mainly oriented to provide value-added comfort applications, Internet access and multimedia. Some examples are context-aware touristic guidance, video on demand and video conferencing.

Although many of these applications have hitherto been proposed together with specific protocols designed from scratch, researches have recognized this is not a scalable way of supporting multiple services within the same information system. With the exception of some services, such as multimedia or common Web access, many ITS applications require a communication strategy that falls within one of the next two groups (or both of them):

- **Periodic status exchange**. Messages needed by applications to know about the status of vehicle or roadside terminals. These exchanges are usually data packets periodically sent by a terminal that contain information about location, speed or terminal identifier, among others.
- **Asynchronous notifications**. This kind of messages are used to inform about a specific event. In contrast to the previous status messages, the reliable delivery of these messages to a single terminal or a group of them is usually a key requirement due to the importance of the information carried.

Examples of the usage of the first messaging type can be found on traffic efficiency applications such as remote vehicle monitoring, which gathers periodic status data from vehicles, or safety applications such as cooperative collision avoidance, which requires kinematic information about surrounding vehicles to detect potential impacts. Asynchronous notifications are mainly found in safety applications, such as slippery pavement or post-collision warning.

Due to the proliferation of numerous ITS applications requiring the usage of these two communication strategies, according to the ISO/ETSI reference ITS communication architecture (Kosch et al., 2009; European Telecommunications Standards Institute, 2010a; International Organization for Standardization, 2013), ETSI has defined two basic messaging services (also known as *facilities*) included in the communications stack as a common reusable middleware. These are the Cooperative Awareness Basic Service (European Telecommunications Standards Institute, 2011), defining the *Cooperative Awareness Message* (CAM), and the Decentralized Environmental Notification Basic Service (European Telecommunications Standards Institute, 2010b), which specifies the *Decentralized Environmental Notification Message* (DENM).

The ISO/ETSI reference ITS communication architecture considers Personal, Vehicle, Roadside and Central ITS Stations communicating by means of an ITS network to provide cooperative services. In this frame, CAM messages are exchanged among them to notify their presence, position and status in a single hop distance through a wireless channel, which is understood to be a wireless communication link based on the IEEE 802.11p technology and following the ETSI G5 specifications. On the contrary, DENM messages can be transmitted in a multi-hop way to cover a concrete geographic dissemination area. Both the format and the conditions under which CAM and DENM messages are generated are also specified by their corresponding international standards, although there are implementation decisions that are left for the developer.

CAM and DENM implementations on vehicular communications stacks are limited, and their support on commercial products is almost nonexistent so far. Due to this, its evaluation on real vehicular environments using the communication technologies conceived for the transmission of these messages is a pending issue in the literature. In this paper, a reference communications stack that follows the ETSI/ISO reference ITS communication architecture is used as the basis for integrating both CAM and DENM messaging facilities. This prototype implementation has been used to validate these basic services in two ways. On the one hand, in order to verify the capabilities of CAM and DENM, two real ITS applications have been developed for tracking vehicles and disseminating traffic incidences. On the other hand, a real semi-urban testbed has been deployed for validating these facilities and assessing the performance considering factors such as vehicle speed, signal quality, message dissemination rules, etc.

While the CAM and DENM packet structure is completely standardized, the message generation algorithms are only briefly described textually by ETSI. In this paper, reference algorithms compliant with available specifications are presented in detail. Apart from the great experimental effort to also validate ITS application services in real driving environments, the following novel contributions are presented and tested:

1. CAM and DENM messages are transmitted using IPv6 multicast over 802.11p/ETSI G5.
2. The Roadside ITS Station forwards CAM messages from the Vehicle ITS Station to the Central ITS Station, and forwards DENM messages in the opposite direction.
3. The Central ITS Station includes a facility to distribute DENM messages among Roadside ITS Stations within the target area of the event to be reported.
4. The reference applications developed can also serve other third-party applications on the Internet through Web service interfaces.