CAMAF: A framework to increase safety on the road

Vincent Charpentier*
Faculty of Applied Engineering - Electronics-ICT
University of Antwerp, IDLab-imec research group
Antwerp, Belgium
vincent.charpentier@uantwerpen.be

Erik de Britto e Silva*
Faculty of Applied Engineering - Electronics-ICT
Smart Networks and Services
University of Antwerp, IDLab-imec research group
Fondazione Bruno Kessler
Antwerp, Belgium, Trento, Italy
erik.debrittoesilva@uantwerpen.be, edebrittoesilva@fbk.eu

Seilendria Hadiwardoyo*
Faculty of Applied Engineering - Electronics-ICT
University of Antwerp, IDLab-imec research group
Antwerp, Belgium
seilendria.hadiwardoyo@uantwerpen.be

Johann Marquez-Barja*
Faculty of Applied Engineering - Electronics-ICT
University of Antwerp, IDLab-imec research group
Antwerp, Belgium
johann.marquez-barja@uantwerpen.be

***Abstract*—Cooperative Intelligent Transportation Systems (C-ITS) deploy the Cooperative Awareness Basic Service to exchange Cooperative Awareness Messages (CAMs) among road C-ITS entities, e.g., vehicles and roadside units (RSUs). CAMs support vehicular safety and traffic efficiency applications that require continuous status information of surrounding C-ITS entities. These messages provide awareness of traffic information in the Non-Line of Sight (NLOS) of the vehicle and are an essential feature to guarantee safety in vehicles. Typically, applications to display CAMs depend on specific C-ITS hardware and software, which implies that each researcher and the industry must develop an application in software and hardware. In this paper, we propose a framework to support research on CAMs through a monitoring dashboard, deploying a portable environment named CAM Application Framework (CAMAF); it manages the received CAMs and updates a corresponding specific monitor for each active C-ITS entity. Each monitor is configurable by choosing CAM fields and making or changing algorithms to display the desired information. We have tested our proposal in a C-ITS testbed with real live traffic.**

***Index Terms*—autonomous driving, C-ITS, CAM, ITS, RSU, testbed, V2X, CAMAF, vehicular communications.**

I. Introduction

There is a significant increase in the number of vehicles on the road. This trend is believed to maintain for the next decades globally [1]. The fact that road accidents increase as the number of vehicles on the road increase seems to imply a link between the two. Cooperative Intelligent Transportation Systems (C-ITS) can be a solution to decrease or eliminate road accidents since it supports connectivity between road and user applications, which aims to increase road safety, efficiency and driving comfort [2].

Cellular Vehicle to Everything (C-V2X) is the access technology for C-ITS to increase safety, increase traffic-management efficiency, and eventually to improve autonomous driving [3]. C-V2X uses Cooperative Awareness Messages (CAMs), periodically sending status data to neighboring nodes [4] as shown in Figure 1. C-V2X technology is essential for the growth of autonomous driving systems in the years ahead [5].

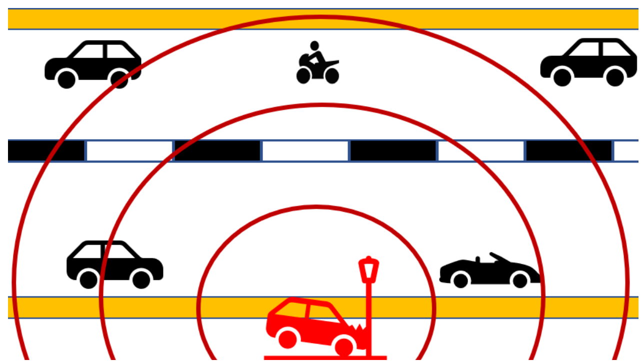

Fig. 1. Cooperative Awareness Messages

Furthermore, autonomous driving systems should not only rely on sensors embedded in the vehicle. Therefore, autonomous driving systems need to be aware of the surroundings via communication (CAM) [5]–[7].

This paper proposes a monitoring dashboard to support research on CAMs and a framework to develop CAM applications called CAM Application Framework (CAMAF).

II. Framework Development and Setup

In this section, we present our CAM application for a use case. Next, we discuss the individual components. We test our use case on the Smart Highway testbed in Antwerp, Belgium [8], as shown in Figure 2.

A. Use case

Vehicles driving on a highway suddenly come to a standstill due to a traffic jam caused by an accident ahead in the Non-Line of Sight (NLOS). This traffic situation is hazardous for rear-end collisions. According to the Belgium traffic management institute (VIAS), rear-end collision accidents are the second most common type of traffic accidents on the

Fig. 2. Location of the RSUs along the Smart highway [11]

highway [9]. To help this type of accident, we implement our CAM application. It monitors all incoming CAMs from police cars at the accident site, blocking the corresponding traffic lane. The driver becomes aware because the application shows different colors on the screen. Using green color, it displays the CAMs of police cars up to red when the driver needs to take action. This way, the driver notices a dangerous traffic situation that is coming such he can prepare himself/herself. If the danger is imminent, the application shows additional traffic information. The allowed speed limit when passing the accident, to which lane the passing vehicles need to move, and if the siren and light bars of the police car are active. The application makes rear-end collision accidents less likely to happen because the drivers know the situation in advance, in the Non-line-of-sight (NLOS). It also makes it safer for the emergency on the site of the accident.

B. Technologies

1) Smart Highway: We test all technologies in the Smart Highway testbed along the E313 highway located in Antwerp [8]. The testbed consists of a highway strip of 4 km equipped with Roadside Units (RSUs) as shown in Figure 2. The Smart Highway is designed for vehicle-to-everything (V2X) communication and distributed/edge computing research [10]. Our test vehicle is a BMW X5 xDrive25d LO enhanced with an Onboard Unit (OBU), power system and communication hardware. This test vehicle can be driven and used as a mobile node on the Smart Highway.

2) CAMINO: The CAMINO framework is a flexible hybrid V2X connectivity platform for the Cooperative, Connected and Automated Mobility (CCAM) services [11]. It provides integration with existing and future short and long-range V2X technologies such as ITS-G5, C-V2X PC5, and C-V2X Uu (5G/4G). The generated messages can be transmitted in a flexible way by one or multiple V2X technologies, increasing the transmission capacity or enhancing the transmission reliability. CAMINO is developed by the IDLab research group, part of IMEC.

3) DUST: The Distributed Uniform STreaming (DUST) [12] framework is a communication middleware for distributed applications, enabling transport-agnostic applications to communicate. It provides a software interface to create software modules dynamically placed over heterogeneous networks from the cloud to edge devices. DUST is developed by the IDLab research group, part of IMEC.

C. Developed tools

1) CAM generator: To generate each CAM message, we developed a custom CAM message generator. We use a roadside unit (RSU) along the Smart Highway [10] to transmit the same CAM message as if they were coming from a stopped police car. These CAM messages are sent over a DUST channel to the CAMINO framework. CAMINO sends the CAMs to the vehicle that runs the CAM service for our use case.

2) CAM decoder: The developed CAM message decoder decodes CAMs. It runs in the vehicle that receives the CAMs along with a running CAMINO core. It receives the CAMs over a DUST channel from the CAMINO core. Every decoded CAM is stored in a JSON file. Furthermore, if the received CAM has the information of a safety vehicle, the decoded content is sent to the CAM web server over a DUST channel.

3) CAM web server: The CAM web server runs in the same vehicle where the CAM decoder and CAMINO core runs. It uses the Spring Boot project [13] as the web application and also our developed CAM application framework (CAMAF) to monitor all CAM messages.

4) CAM application framework (CAMAF): We developed a CAM application framework called CAMAF. It is designed to be dynamic, aiming to be the core framework for managing CAMs received by vehicles. The framework generates or updates every received CAM into the corresponding specific monitor; based on the station ID and the station type of each vehicle. During our experiments an RSU transmits custom CAMs, CAMAF updates these monitors every time a new CAM is received. CAMAF can monitor the following CAMs via the station type: unknown CAMs, pedestrians, cyclists, mopeds, motorcycles, passenger cars, busses, light trucks, heavy trucks, trailers, special vehicles, trams, and roadside units.

We illustrate the flexibility of CAMAF with an example: suppose yourself driving a vehicle on the Smart Highway, surrounded by four vehicles that send one CAM every second. Then the service controller inside CAMAF generates a specific monitor that follows a specific algorithm according to the station type.

It also updates the individual monitors when a new CAM arrives from those specific vehicles. The service controller manages all monitors of every group of station types according to a specific algorithm. This algorithm can be different for every vehicle type. Furthermore, CAMAF makes it possible to implement multiple custom algorithms for every station type and to switch between them in real-time. For example, if it needs to monitor a special vehicle differently, we write a new custom algorithm and plug it in the special vehicle monitor of CAMAF. Additionally, every monitor can become aware that a vehicle has stopped sending CAMs. When it happens, the monitor terminates via a configurable interval; by default, a monitor terminates when it has not received a new CAM for more than one second. It happens when the two vehicles are too far from each other to receive CAMs or when the sending vehicle stopped sending CAMs. If one of these four vehicles leaves the Smart Highway, then the specific monitor for that vehicle terminates automatically. Now, only three monitors run in the vehicle, one for each surrounding car.

CAMAF also deploys a Global Navigation Satellite System (GNSS), retrieving positioning data with a configurable interval from an external GNSS device. The latitude, longitude, and altitude are used to track the distance between vehicles that receive the CAMs (where CAMAF is running on) and the sender vehicle. Every received CAM also contains the latitude, longitude, and altitude of the sending vehicle. If the distance between the sender and receiver increases over a configurable limit, then CAMAF ignores those messages.

The CAM application monitors multiple police cars near the place of the accident, and we propose a priority variable to filter the received CAMs. The vehicle driver becomes aware only of the most priority CAM when he has an application service running. The priority increases when the driver receives more CAMs from that specific vehicle. On the other hand, the priority decreases when the monitor stops receiving CAMs every second. When there is no CAM received for five seconds, the monitor terminates automatically. We explain this feature with an example, a vehicle and three special vehicles, three police cars named A, B, and C, driving on the highway. Three monitors are running in the vehicle, one for each police car. Suppose that the police cars are blocking the right lane due to an accident. Police car A is sending CAMs informing that light bars and siren are active, it is a “heavy accident”, and has the road speed limit changed to 50 km/h. Also, police cars B and C are sending the same type of CAMs, except they do not specify the speed limit. If the driver is using our CAM application which uses CAMAF, the driver only becomes aware of the CAMs sent from police car A. Since CAMs sent by police car A contains more safety-critical information comparing to police cars B and C, namely a new current speed limit. So, the driver becomes aware in advance that the traffic slows down ahead. Consequently, the driver can prepare himself and take the needed safety actions.

III. Framework Deployment

This section presents our CAM application experiments on the Smart Highway testbed.

A. CAM dashboard

The dashboard, in order to display the received CAMs, adapts itself to a PC, smartphone, or tablet screen via an Internet browser.

B. CAM web server

Our CAM web server uses the CAMAF framework, and it displays the messages delivered by our CAM decoder. In our use case, the CAM decoder delivers CAMs from special vehicles only. This way, when an accident happens on the highway, the police close the lane where it happened. Consequently, all incoming traffic on the highway must merge into the available lanes. It is a dangerous situation for the people from the emergency services and the road users driving along the highway. In addition, it can lead to other accidents. CAMs are suited for that, as they inform the driver of what is happening over the NLOS. The CAM web server is responsible for displaying the dashboard with the data, images, and different colors to inform the driver.

C. Screen colors application

A study performed by Chen-hao Dong et al. [14], concluded that when drivers use smartphone navigation, their attention is distracted. By focusing too much on the inside of the car, their attention on the road is reduced. Therefore, our CAM application displays different colors on the screen. We choose it for multiple reasons. First, in less than a second, the driver can look at the colored screen. Second, the colored screen informs the driver much faster than when he needs to read text messages. Third, the colors start from green and loop over every color between green and red. Fourth, it provokes a familiar feeling because we always see red as an important event, e.g., a red stoplight, and green as a safe event, e.g., a green stoplight. Finally, we see yellowish colors as the transition from a safe to a possible dangerous event, e.g., a yellow stoplight. The application also displays panels with additional information. The station ID, station type, speed value, speed limit, siren activated, light bars activated, priority, and distance are among them.

Figure 3 shows the screen the driver sees in normal conditions. It means there are no CAMs received from special vehicles, and everything is normal on the road, indicated by the green background. From the moment CAMs are received from special vehicles, our CAM application becomes aware and makes the driver aware of the special vehicle, turning the screen background to a yellowish color. This way, the driver becomes aware that a dangerous situation is happening within a certain distance ahead. Additional information is displayed to the driver when the confrontation is imminent. It also displays an icon of the current speed limit. Figure 4 shows an icon with the type of the special vehicle that sends the CAMs. The driver is also aware that the siren and light bars of the police car is activated by an icon displayed on the screen. The CAM application loops over these icons such that every icon is displayed for a period of one second. When the vehicle that uses our CAM service passes the accident, the application will display the content as shown in Figure 3. CAMAF automatically stops monitoring this special vehicle when it has passed the accident.

IV. Discussion

We consider CAMAF essential framework to develop future CAM applications. To the best of our knowledge, there are not many frameworks to develop CAM applications in the

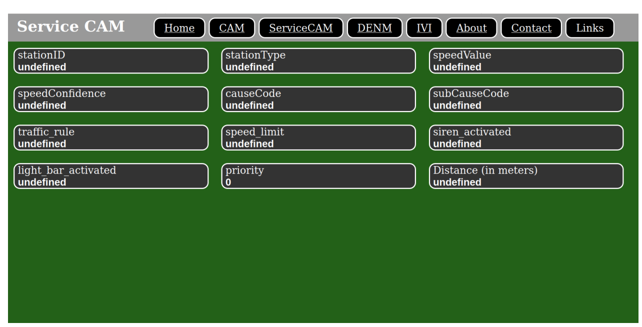

Fig. 3. Default screen

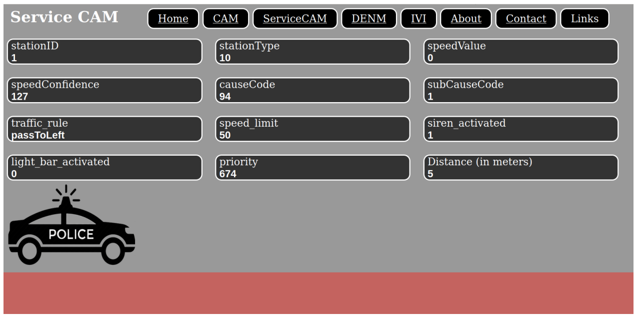

Fig. 4. Displaying the type of special vehicle that is sending CAMs

literature. Moreover, research can be done about optimal ways to monitor CAM messages and better display them to the driver. Therefore, we can focus the research on developing more complex algorithms to monitor CAM messages.

We can do research in better ways to display the CAM, like in a head-up display, such that the driver does not need to take his eyes off the road. We can also use the vehicle comfort elements, like the ambient lighting, to make passengers aware of specific CAMs. This way, lights can blink with different colors according to the received CAMs.

Another topic for research is deploying sound effects to make the driver aware of CAMs, using the built-in audio system of the vehicle. We can do behavioral research on how the sound affects the users. Questions that need to be solved are: "Do road users need to be trained to get used to the sound effects?", "What extend should road users rely on the sound effects?", "Into what extend-noise on the road, radio, and other factors interfere with the sound effects?", "If sound effects suffer interference, will it confuse the road users and cause accidents?". We can deploy different sound effects to show different CAMs and their relevance.

V. CONCLUSION

In this work, we introduce the need for CAMs in the C-ITS environment. Then we present the CAMAF framework and setup to support research on CAMs via a monitoring dashboard.

To validate our solution, we present a CAM dashboard application. Our solution is software-based so it is portable to testbeds or experiments agnostic of specific hardware, using CAMINO [11] and DUST [12].

CAMAF is under development, but we consider it a convenient framework for developing future CAM applications for different C-ITS use cases.

As future work, we intend incorporate custom algorithms to monitor other station types and other use cases. We also intend to assess the scalability of our application with more vehicles, and research how to display CAMs in a smarter and safer way.

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