Cooperative ITS for Two-Wheel Vehicles to Improve Safety on Roads

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***Abstract*—Research efforts carried out on Intelligent Transportation Systems (ITS) for improving safety and efficiency of road transportation have been focused on cars, where vehicular communications have demonstrated to enhance the driver awareness with active services that improve fatality statistics. Although common vehicles accidents have been reduced in the last years, those involving vulnerable road users remain. Cyclists and motorcyclists cover a whole area where ITS and telematics should be embedded with no doubt, given the incremental popularity of bikes and motorbikes in urban mobility and short inter-urban routes. For this reason, this work takes the key objective of integrating two-wheelers within the future cooperative ITS network. Hence, a novel communication device especially adapted to cyclists and motorcyclists has been designed, by integrating vehicular wireless communications (i.e. IEEE 802.11p) and considering interface limitations. From the protocols perspective the work is focused on IPv6, and considers two-wheelers as part of the Future Internet. In fact, a great success of the proposal is exploiting the synergy between IETF (Internet) and ITS-specific protocols coming from ISO and ETSI, creating a novel active system to improve two-wheel transport safety through Cooperative Awareness Messaging (CAM) over IPv6. The embedded communication node for two-wheelers includes the proper software to warn the driver about the approaching of a regular vehicle through audio and visual notifications. Moreover, its counterpart for common cars has also been developed, but using an Android application running on a handheld device connected to a regular IPv6 in-vehicle network.**

I. Introduction

Recent statistics from the Community Road Accident Database (CARE) show that road fatalities in Europe for bikers and powered two-wheelers has barely reduced in the last years, as compared with the year-by-year cut in common vehicle accidents. We are taking the risk of enlarging this number with the popularity of bikes, mopeds and motorbikes in new urban mobility models. These numbers also reveal that most of the deaths are consequence of a collision with common vehicles, which means that a proper communication strategy among all vehicles on the road would save lives, time, and money.

Cooperative Intelligent Transportation Systems (C-ITS) are demonstrating to improve safety and mobility of common vehicles, as it has been reported in recent results of European projects like Drive C2X [1] or FOTsis [2]. These systems stretch the range of isolated systems powered with sensors to better maintain contextual information about the surrounding traffic, thanks to wireless communication technologies. Vehicular networks have reached a standardization stage, since they are recognized to save lives and improve travel experience. However, the work in this area focused on two-wheelers is almost null. Bikes, mopeds and motorbikes have special constraints that make them a different vehicle group to be integrated in the future communication network. Power source, mobility patterns, vehicle dimensions, communication range, positioning capability, human-machine interface (HMI) or electronics integration are some of these particular features. The potential of C-ITS in the two-wheel segment is clear, but a proper technological platform is needed to provide effective safety and mobility services.

The work described in this paper exploits this new research area, where C-ITS fills the technological gaps to provide safety and efficiency services for two-wheelers. For this, the proposal raises from the synergy between current ITS standards (ISO/ETSI), Internet protocols (IETF) and IEEE technologies. The solution is an embedded communication unit for two-wheel vehicles integrating IEEE 802.11p wireless technology in a small-factor computer, and running a communication middleware based on IPv6 and Cooperative Awareness Messaging (CAM). A safety service has been developed for both the two-wheeler and common vehicle sides, with the aim of preventing fatalities and injuries in this group of vulnerable road users (VRU).

The paper is organized as follows. Section II places this work in the research literature. Section III describes the general scenario of the ITS communication system. Sections IV and V describe the most relevant hardware and software parts, respectively, of the embedded communication unit proposed. Finally, Section VI concludes the paper and describe the next steps in our work in progress.

II. State of the Art

A proper scientific knowledge supporting the application of C-ITS technologies in two-wheelers is still lacking in the literature. Several works in the literature already deal with road safety regarding VRU, but mainly focused on pedestrians. Examples of this are [1] and [2], where 3G and WiFi are evaluated to exchange positioning data between mobile phones and car on-board devices to avoid accidents. The authors

[1] http://www.drive-c2x.eu/project
[2] http://www.fotsis.com

in [3] review a communication technology in the 700 MHz for pedestrian to vehicle communication, which is far from current worldwide trend of working in the microwave band. The solution presented in this paper focuses on the use of vehicular WiFi technology in the 5 GHz band for short-range vehicular communications, whose potential for communications between cars and VRU is discussed in [4].

A recent work dealing with the integration of telematics in bicycles can be found in [5]. It is a preliminary system concept in which ZigBee is used to improve travel efficiency through cooperative cruise control in bikes. Although the communication system is apart from current vehicular standards, it shows an interesting equipment embedded in the bike with a haptic interface. The work in [6] lacks from using a proper communication approach (given the work age), but also serves as example of device integration for two-wheelers. It also discusses the potential of wearable devices, as this paper proposes to develop in next steps, involving an alternative to vehicle-embedded devices. In [7] a prototype of connected motorbike uses a communication device installed in the boot with vehicular WiFi (5 GHz). This is a reference research in the motorbike segment, although further work is identified in a protocol stack lacking support with current trendy standards in the segment and not considering Internet connection. The work in [8] is focused on light two-wheel vehicles, presenting a safety system to warn cyclist about the presence of other vehicles through a visual interfaced embedded in the helmet. However, as a difference in the present contribution, it is based on a 3G/4G connection through the mobile phone.

As can be seen, further research efforts are needed to expand the ITS field to embrace two-wheelers through novel approaches in both device engineering and communications, given that it is essential to provide standardized telematic services to the growing number of cyclists and motorcyclists

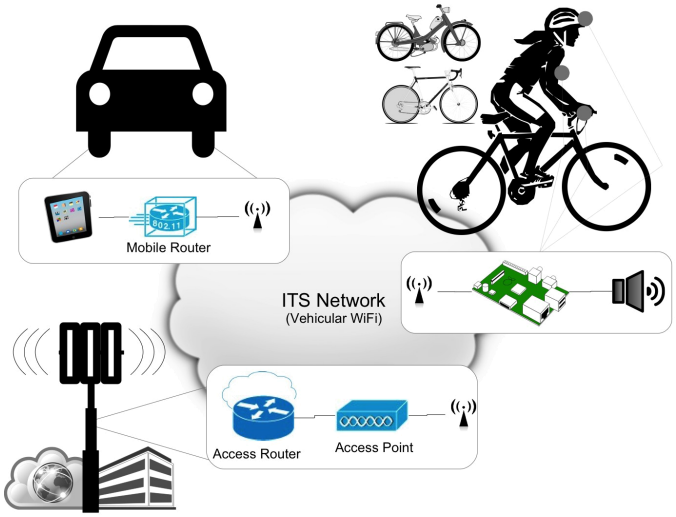


Fig. 1. Overall scenario of the communication system

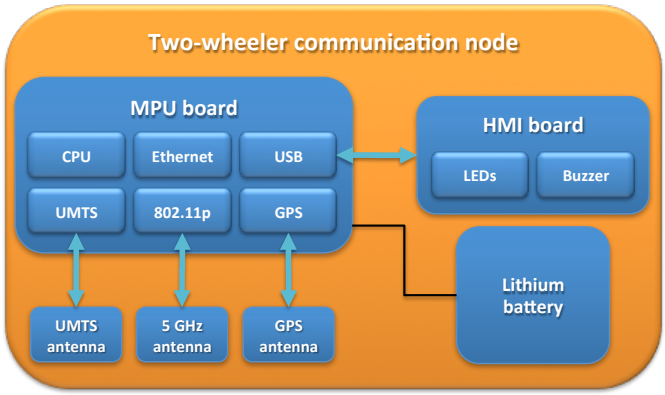


Fig. 2. Hardware design of the communication unit

III. Overall System Architecture

The overall architecture and main subsystems of the proposal are illustrated in Fig. 1. Vehicles are provided with a mobile router with IEEE 802.11p support and a proper visual interface unit connected through an in-vehicle network. The communication stack is based on IPv6, as it has been successfully tested by us in [9]. Over this stack, a message exchange using standardized ETSI messaging is used to develop a novel cooperative safety application for two-wheelers, which are equipped with a communication node supporting vehicular WiFi. This unit has been prototyped as an embedded on-board device powered with a battery, and including GPS and an 802.11p transceiver. The communication stack of this unit is based on an IPv6 over IEEE 802.11p, with the aim of enabling the interconnection of bikes with common vehicles and infrastructure. Moreover a messaging subsystem has been developed together with an embedded safety application to make aware the VRU of the surrounding cars. An HMI has been designed to improve the driver awareness. Finally, the communication with the infrastructure can be carried out through roadside units provided with access router and vehicular WiFi communication, as used in [9].

IV. Embedded Hardware Platform

A new communication unit has been designed for the case of two-wheel vehicles, including necessary communication technologies and providing a proper software host. The general structure of the unit is depicted in Fig. 2. The microprocessor unit (MPU) board contains the base platform, with the CPU, USB, and communication modules supporting UMTS (3G), vehicular WiFi and GPS. The main board is powered by a battery, given that the two-wheel vehicle could not include power supply (e.g. bikes). The human-machine interface (HMI) is given by an extra board including LEDs and a Buzzer, as can be seen in the diagram. A simple interface has been designed given the limitations of the driver to interact with the unit. One of the LEDs indicates the operation mode of the unit, while the others blinks at a given frequency indicating that a potentially dangerous vehicle (car, truck, etc.) is approaching. The buzzer also indicate this fact but beeping to warn the user.

A prototype of the previous unit design is being implemented, and most of the work is covered. Fig. 3 shows the main parts of the hardware. Fig. 3a includes a photo of the MPU board, which is based on the Laguna LGN-20 platform from Commsignia. The communication board is visible on the top, from where different cables are connected to the 802.11p, WiFi (802.11n), GPS and 3G antennas. This system mounts an ARM11 300MHz SoC processor, 16 MB of Flash and 8 GB of internal storage, and 256 MB of RAM memory. It is important the USB interface visible on the lower part of the image, since it is used to connect the HMI board. The 802.11p antenna is a 5.9 Ghz Taoglas Limited DCP.5900.12.4.A.02 (6 dBi) that is prepared to be affixed to the inner part of the unit enclosure; whereas the GPS antenna is a PCTEL WS3917, which is connected externally to avoid interferences and improve coverage. The power supply used is a 15 volts and 3500 mA lithium battery, which is able to maintain the unit up more than five hours, according to our initial tests.

The HMI board is a new design, whose first prototype is the one in Fig. 3b. Three LEDs are used to inform about the whole unit status (one of them) and warn the driver of the presence of common cars in the surroundings. The buzzer is clearly visible on the lower-left corner of the board, while the USB connector is used to connect the circuit to the main board, as indicated.

V. Communication Middleware and Safety Service

Both two-wheel and common vehicles execute a software in charge of gathering their positions and exchange them (together with other data) with surrounding vehicles. This way it is possible to calculate the distances between them and implement proximity warning services that prevents the presence of vehicles in potentially dangerous positions. In order to achieve this, a standard messaging scheme has been used, using CAM messages standardized by ETSI.

The on-board middleware has been organized in a set of independent modules, each one performing a well-defined and unique task. The overall design is included in Fig. 4, where status data emission and reception are clearly visible on the left. *CAM Sender* and *CAM Receiver* modules are responsible for keeping direct contact with the system network interfaces, with the aim of sending and receiving CAM messages in DER-ASN.1 format as defined in [10]. CAM Sender and CAM Receiver send/receive CAM messages encapsulated in UDP datagrams by using a configurable port number on the multicast IPv6 address *ff02::1*. All nodes must be able to listen to any sender present in the same local network, using link-local IPv6 addresses and joining this multicast group.

When a node receives a CAM message, it is passed to the *CAM Coder* module to be translated to XML, which makes easier subsequent data extractions. The *ASN.1 Compiler (asn1c)* [3] has been used in our implementation to generate a translator easily upgradable. After the conversion, *CAM Processor* can parse the information included updating the

[3]http://lionet.info/asn1c/compiler.html

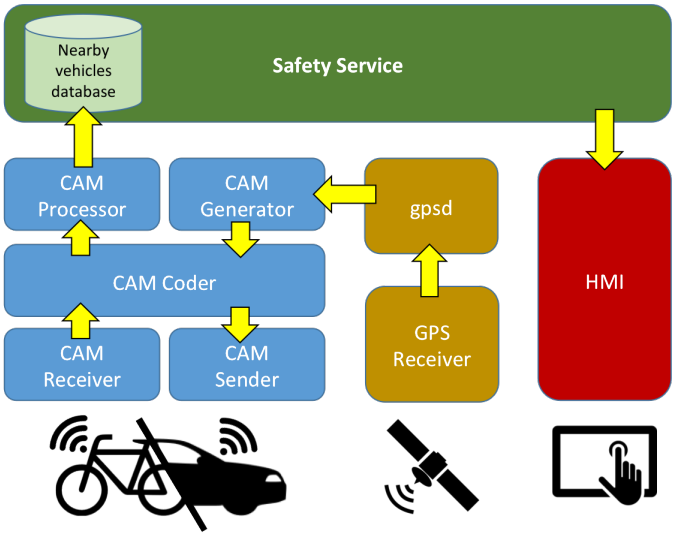
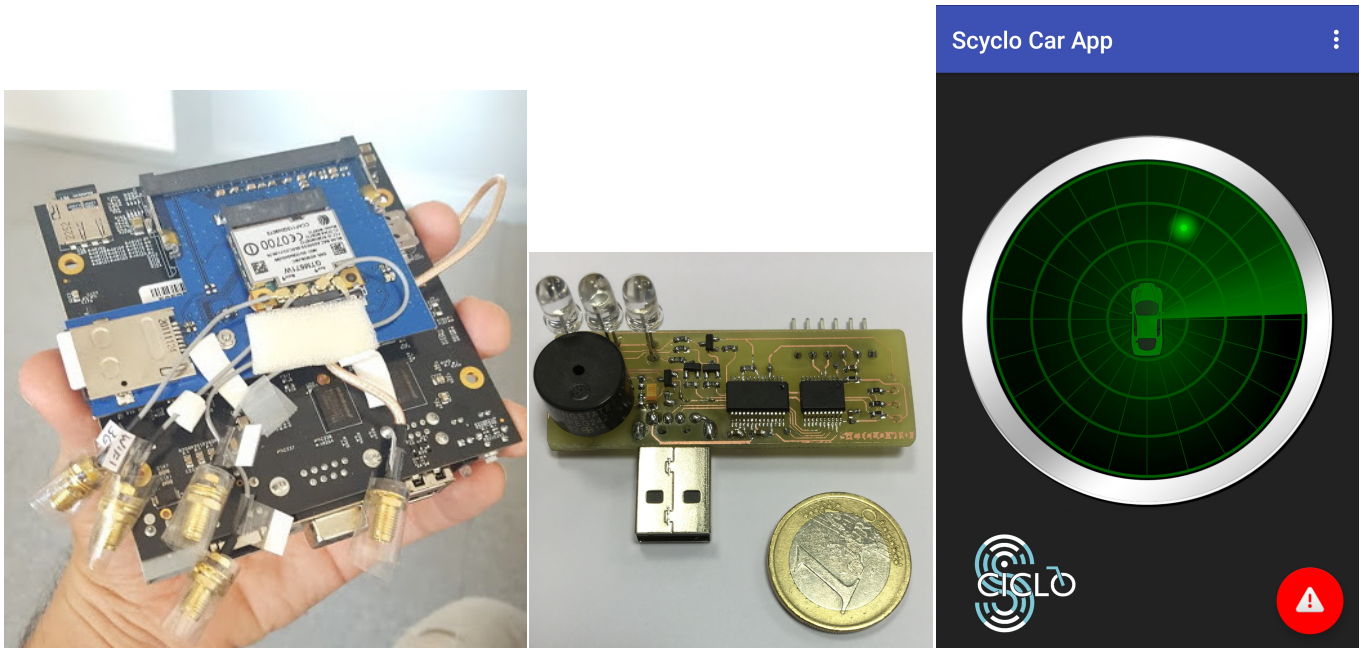


Fig. 4. Modular software design of the safety middleware

local database of nearby vehicles, and then allowing the *Safety Service* to calculate the distance between the ego-vehicle and the one informed.

CAM Generator is the module in charge of gathering information about the status of the vehicle (position, speed, course, etc.) to generate new messages to be emitted. The base information needed to create new messages is taken essentially from the GPS device, although other data regarding the type of vehicle is taken from a local configuration dataset. The GPS information is currently gathered by the *GPS Receiver* module, which receives geo-location updates in JSON format at 1 Hz rate from the *gpsd* service.

The safety middleware has been designed to be present in both two-wheeled and common vehicles. However, the operation of the whole software unit depends on the type of vehicle, attending the final application functionality. When running in vulnerable (two-wheeled) vehicles the software warns the user upon the approach of a common vehicle in the surroundings, since it supposes a threat for driver safety. A higher frequency of the blinking LEDs (two of them are used for this purpose) and the beep from the buzzer are used to notify the closeness of a four-wheel vehicle. Regarding common four-wheeled vehicles, they run the communication middleware in a mobile router with higher capabilities. The drivers are also warned about the proximity of vulnerable two-wheeled vehicles, letting them paying special attention to them. In this case, the HMI is uncoupled from the communication unit, and it is implemented as an Android app that receives the proximity notifications from the mobile router through an in-vehicle network provided by a WiFi. The mobile router is 802.11p-capable and receives the CAM messages from vulnerable vehicles. The safety service calculates the distances and detects potential hazard situations that are showed in the HMI. Fig. 3c illustrates the layout of the app developed in Android. It shows in a radar-based display the location of



(a) MPU board of the embedded unit (b) HMI board for two-wheeler (c) Screenshot of the Android app

Fig. 3. Hardware and software prototypes of the system

vulnerable vehicles in the surroundings, which also uses sound alerts to warn the driver if needed.

VI. Conclusion

This paper describes the development of a communication unit and software to allow two-wheel vehicles to be connected to future vehicular communications. A reference safety service has been developed and, in general, the communication middleware based on CAM messaging works on both the embedded unit for bikes/mopeds/motorbikes and a mobile router installed in a common vehicle to provide network access to occupants. A prototype of the embedded unit has been implemented, and the only component under development is the enclosure, which is supposed to be appropriate to be affixed on the two-wheeler body. Future prototypes will be developed with the aim of miniaturizing the unit to be worn in a bracelet or helmet, for instance. Next steps comprise the finalization of the Android app and exhaustive performance tests, given that initial validation tests indicate the correct operation of the unit. Moreover, apart from vehicle-to-vehicle scenarios, it is planned the provision of vehicle-to-infrastructure communications not only using IEEE 802.11p communications, but also 4G networks; all of this within a Smart City environment embracing all transportation means.

Acknowledgment

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