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ScienceDirect

Procedia Computer Science 160 (2019) 473–478

Procedia Computer Science

www.elsevier.com/locate/procedia

The 3rd International Workshop on Connected & Intelligent Mobility (CIM 2019)
November 4-7, 2019, Coimbra, Portugal

The COVCRAV project: Architecture and design of a cooperative V2V crash avoidance system

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Abstract

Systems capable of warning motorists against hazardous driving conditions are extremely useful for next-generation cooperative situational awareness and collision avoidance systems. In this paper, we present some preliminary results related to the COVCRAV project which aims to develop an on-board Road Hazard Signaling (RHS) system based on a crowd-apprising model. Unlike other approaches that rely on the automatic detection of dangerous situations via onboard sensors or warning messages received from roadside units, our approach enables drivers to interact directly with a touchscreen Driver Vehicle Interface (DVI) to notify nearby vehicles about the presence of a hazardous driving situation based on many high-value safety use-cases. We describe our RHS application and highlight the key functions provided by the originating and the receiving ITS applications. We also provide some details regarding the design aspects and system architecture of the proposed system.

Keywords: Intelligent transportation systems; road hazard signaling; crowd-apprising; V2V applications; road safety, cooperative systems

1. Introduction

Despite the impressive progress in vehicle safety, road traffic injuries remain a serious public concern as they are

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10.1016/j.procs.2019.11.062

the leading cause of death for children and young adults aged 5-29 years [1]. According to the World Health Organization, around 1.35 million people die each year as a result of road traffic crashes [1]. There has been a growing number of research initiatives towards connected vehicular systems based on V2x technologies that would allow intelligent road-side units (RSUs) and vehicles to cooperate for enhanced awareness of driving conditions. However, in order to act on their surrounding environment, these assistance systems often depend on sensor-based mechanisms to automatically detect the presence of a road hazard. In this contribution, we take a different approach by proposing a cooperative onboard Road Hazard Signaling (RHS) system based on a crowd-apprising model instead. This approach will eventually enrich the information available for ITS purposes. The proposed RHS system is being developed as part of the **Co**nnected **V**ehicle **Cr**ash **Av**oidance (COVCRAV) project. It should be noted that the proposed system is not intended to guarantee crash avoidance, but rather to contribute towards crash mitigation by enhancing drivers' vigilance. Hence, with reference to ETSI Technical specifications [2], the performance requirements of this secondary safety application are less strict than for collision avoidance and therefore a class B performance is deemed acceptable.

The remaining of this paper is organized as follows: Section 2 presents an overview of noticeably related road safety projects. Section 3 summarizes the key functional requirements of the proposed RHS system, while section 4 provides a brief description of the key functions provided by the originating and the receiving applications. In section 5, we present details regarding the design aspects and system architecture of the proposed system and finally, in section 6, we conclude by providing a summary of the paper and the ongoing research.

2. Literature review and research contribution

For the past few years, many consortia, organizations and research entities have been actively engaged in in many integrated R&D projects that aim to explore and promote the usage of V2x communication as a basis towards next-generation intelligent transportation systems. Among the most noticeable projects, we can cite PreVent[3], CVIS[4], SAFESPOT [5], COOPERS [6],SeVeCom [7],COMeSafety [8],INTERSAFE-2 [9],GeoNet [10], and FOTsis [11]. These projects differ in many aspects, including scope, problem being addressed, choice of communication technology, targeted applications, and design intent, among many others.

Unlike earlier approaches that depend on the infrastructure and the vehicles' onboard sensors as the sources of the safety-related warning information [12], this research suggests that drivers can act as the sources of the road hazard warning, which can be signaled to other vehicles using standard V2x communication. COVCRAV is a specific customized implementation of an ITS V2V application, dedicated for RHS and in accordance with the ETSI ITS standards. The design of the proposed RHS solution is partially inspired from the SIM^{TD} project [13], with several additional enhancements and customizations being added to address the specificities of our crowd-apprising application and to improve performance. The general aims of the COVCRAV project are threefold: First, increase the safety margins of vehicles by incorporating a crowd-apprising model as the trigger of the road hazard detection. Second, lay down the foundation for developing a new breed of intelligent road safety applications based on driver-triggered warnings, combined with cooperative hazard signaling. Third, develop an open, flexible, modular and fault-tolerant Linux-based prototype system to showcase and validate the value propositions of the proposed system.

3. RHS application functional requirements

We have used various requirement analysis techniques to identify the functional and nonfunctional requirements of the project, including brainstorming sessions, mind maps, context diagrams, benchmarking, and document analysis. We have identified and fully documented 6 main use cases, each corresponding to particular road hazard scenario. Most of these scenarios were derived from the ETSI TS 101 539-1 technical specification [2]. These are: adverse weather conditions: Beginning of a low-visibility area (due to the presence of fog, smoke, heavy rain or snow); stationary vehicle ahead; roadwork ahead; stationary traffic ahead, wrong way driving ahead; and presence of a hazardous location (e.g. obstacle on the road, animal on the road, slippery road conditions). In our case, we decided to implement these use cases in one application layer entity as opposed to several specific application layer entities corresponding to different use cases. This will make it easier to cope with the special case where several simultaneous warning requests, corresponding to different use cases, are forwarded to the HMI support function.

4. RHS application description

COVCRAV adopted the decentralized environment notification (DEN) basic service [14] as the basis for the specification of the proposed RHS system.

At the originating ITS station (ITS-S), the user will manually notify the RHS application about a specific road hazard by touching and holding the proper icon displayed on the touchscreen DVI. This action triggers a request for the DEN basic service to execute the corresponding road hazard signaling service and start the DENMs transmission. The OBU geo-broadcasts a Decentralized Environmental Notification Message (DENM) to all neighboring vehicles present in the relevant local area. For all use-cases, some data elements are transferred to the DEN basic service, such as the time at which the hazard is detected and the position of the originating vehicle. Each specific use case will have its own data elements that will be forwarded to the DEN basic service. The DENMs can be relayed over several hops through which distant vehicles can be notified about a potential road hazard. This relay of messages ensures that vehicles located beyond the communication range are informed about the signaled warning and hence can react early enough to respond to the situation.

At the receiving ITS-S, the RHS application will process the received DENMs and visually notify the driver about the road hazard through a labeled popup icon displayed on his touchscreen DVI, which is accompanied by an audible warning as well. It should be noted that the applications at the originating and receiving ITS stations are completely decoupled from each other, with the receiving ITS-S simply receiving and processing the data elements and headers of the received DENMs and triggering the corresponding road hazard signaling and notification.

5. RHS architecture and design

As shown in figure 1, each vehicle is equipped with an OBU that consists of two main boards (Communication Control Unit (CCU) and Application Unit (AU)), in addition to a HMI touchscreen device. V2V communication is established among the cars using the vehicular Wi-Fi (IEEE 802.11p) standard which is the basis for the ITS-G5 standard in Europe; although the CCU also supports urban Wi-Fi (IEEE 802.11b/g/n) and Bluetooth to enable connection to external servers or other devices if required.

Fig.1: V2V communication based on the IEEE 802.11p

Figure 2 shows a high-level deployment diagram of our proposed RHS solution. As may be seen, we have decided to split the CCU from the AU to ensure performance, modularity, ease of implementation, and most importantly better fault-tolerance. In particular, if the AU board is subjected to memory overflow or software bug problems, the V2V communication with other vehicles will remain intact. In this case, the CCU will still be able to relay audio notifications to the driver until the AU is restored to a stable state. To further enforce fault-tolerance, the COVCRAV project makes use of redundancy by duplicating the three core AU components (RHS application, ITS facility layer and Python core) into the vehicle CCU board. This means that if the AU is not restored in time (as reported by the AU bug detector), the CCU can take over the application functionality within 10 seconds by launching the RHS app and interfacing directly with the HMI device, thus acting as a complete ITS station.

It is not the purpose of the paper to get into the details of all the design aspects, the services and their implementations, but rather to give an overview on the overall system design and architecture of the proposed RHS.

5.1. Communication Control Unit (CCU)

As shown in figure 3, the CCU is the central communication device of COVCRAV and is composed of three main units, namely the CCU router, the GPS module and the WLAN subsystem. It has been designed based on the earlier cargeo6 project [15], in addition to the IEEE 802.11p, IEEE 802.11b/g/n and Bluetooth wireless standards.

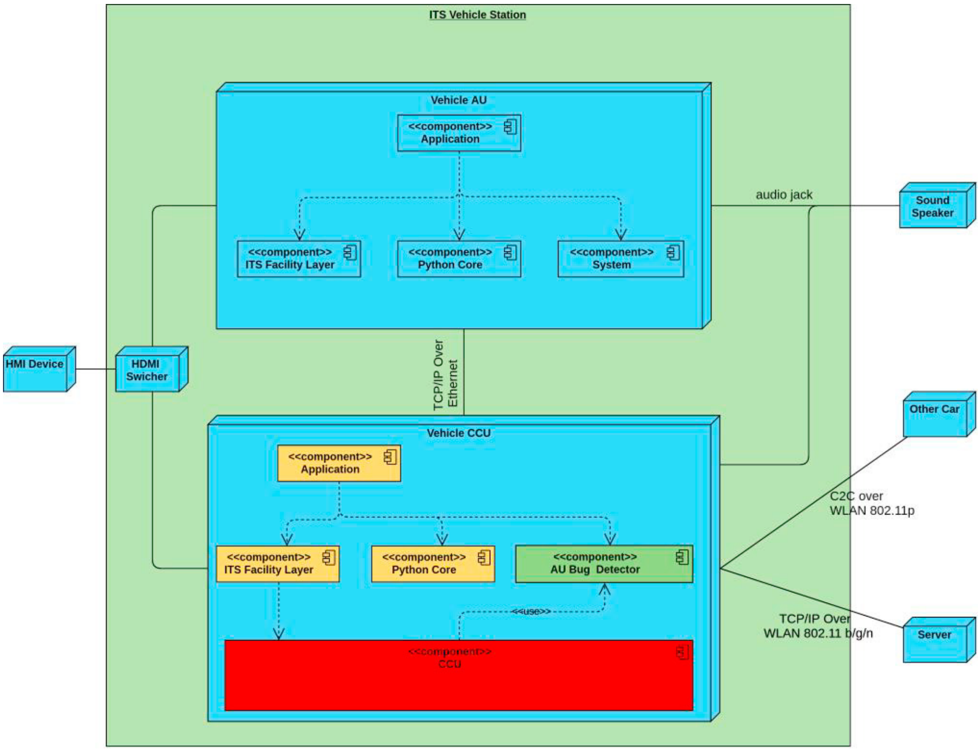

Fig.2: High-level software deployment diagram

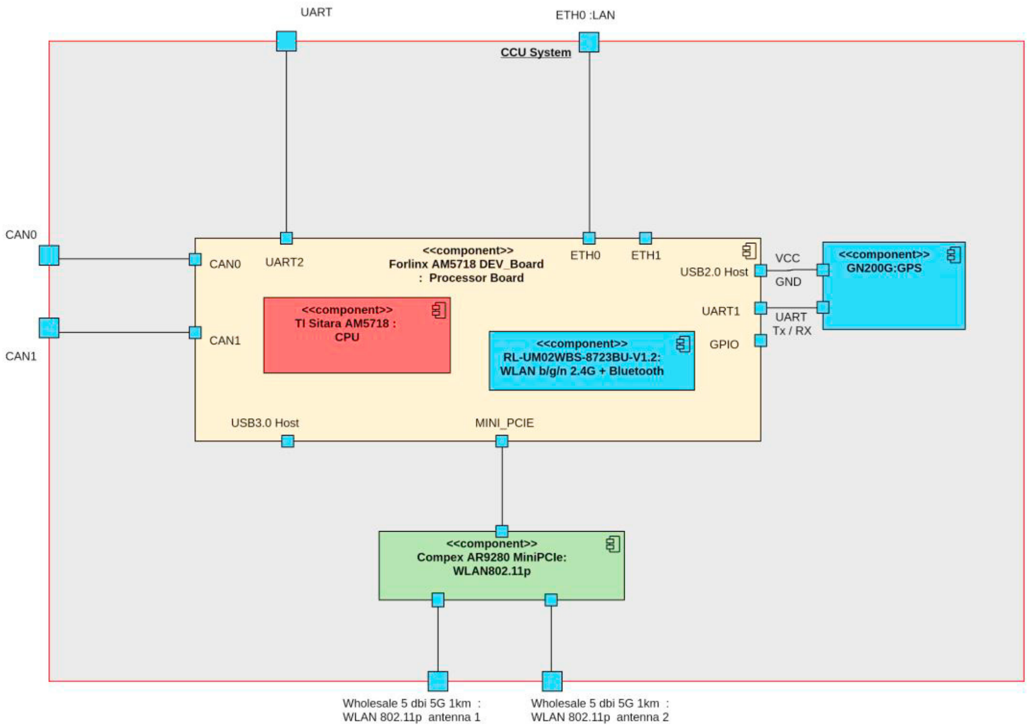

Fig. 3: CCU hardware architecture

The CCU handles the creation of geo-(broadcast/unicast/anycast) packets for transmission to other vehicles based on IEEE 802.11p and it communicates with the AU via fast Ethernet using TCP/IP protocol.

The CCU is implemented using the *Forlinx* OK5718-C development board [16] which is based on a TI AM5718 processor. Although the *Compex* AR9280 WLAN device is designed for the IEEE 802.11a/n standard, we were able through the ath9k patched open source Linux kernel driver to make it communicate using the IEEE 802.11p standard instead. The CCU router is running under a preemptive Real Time Linux Kernel v4.9.41 [17] that supports IEEE 802.11p standard.

Figure 4 depicts the top-level software architecture of the CCU router. As may be seen, the CCU router is composed of four main software components, namely (1) GPS communication service, (2) WLAN communication services, (3) ITS-transport service and (4) Carego6 communication service. These are briefly described in the remaining of this subsection. It should be noted that details regarding the internal architecture of each of these 4 components could not be included herein due to lack of space.

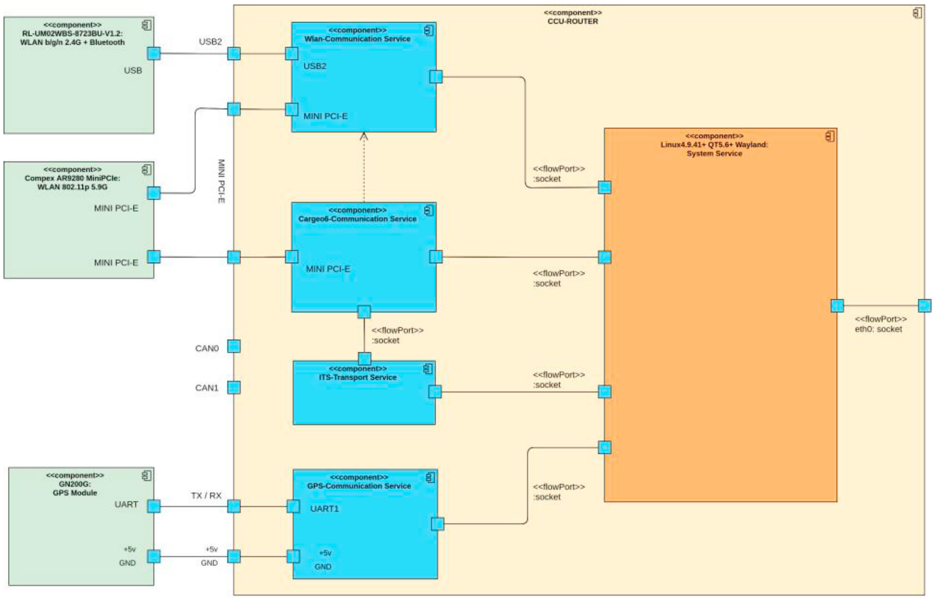

Fig.4: CCU router software architecture

The GPS communication subsystem on the CCU interfaces with an ultra-high performance GN200G GPS module for accurate positioning. The module also generates a timing pulse that can be used for internal timing synchronization directly or via an NTP-server.

The WLAN subsystem enables the exchange of data with other vehicles and/or infrastructure systems via TCP/IP, UDP/IP, or ITS-transport/Cargeo6. The WLAN communication service contains several components including (1) communication ID management, (2) IP configuration, (3) interface selection, and (4) interface configuration.

The Cargeo6 communication service is an implementation of the project *Geonet*, and specifically the deliverable D2.2 final *Geonet* Specification [15] that outlines a safety communication framework. Cargeo6 communication service provides various functions, including (1) message storing and forwarding, (2) neighborhood location table management, (3) beaconing and (4) location services for geo-unicast packet transmission.

5.2. Application Unit (AU)

As shown in figure 5, the AU consists of four main blocks, namely the application, the ITS facility layer, the system, and the Python core components. The AU handles our RHS application and contains some libraries and other components that are required by the application in order to interface with the HMI device and the CCU.

The ITS facility layer is detailed in the ETSI ITS 102 894-1standard [18]. Each ITS station supports two types of facilities: (1) Common facilities that provide basic core service to ensure interoperability among Basic Set of

Applications (BSAs) and enable reliable ITS-S operations and (2) Domain facilities to provide for instance the DEN basic services for our cooperative RHS application.

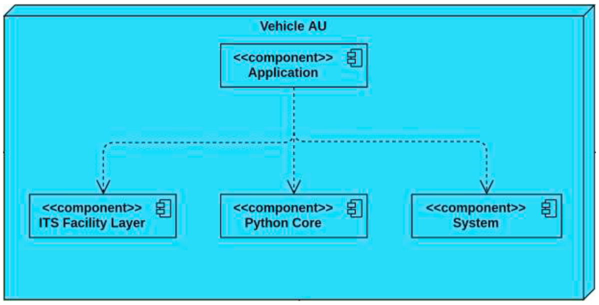

Fig.5: AU deployment diagram

6. Conclusion

In this paper, we have presented a brief overview of the COVCRAV project with a specific emphasis on the design and system architecture of the proposed RHS application. In particular, we have introduced a possible approach to enhance the information availed for ITS safety applications by engaging the drivers as the sources of the road hazard warning. We are currently working on the implementation phase where prototype boards and touchscreen monitors are being programmed. This will be followed by several Field Operational Tests (FOTs), using actual vehicles, to validate and evaluate the performance of our RHS application.

Acknowledgements

This research project is financially supported by Zayed University under the Cluster Research Grant # R17075.

References

[1] World Health Organization (2018). https://www.who.int/en/news-room/fact-sheets/detail/road-traffic-injuries. Retrieved June 2019.

[2] ETSI TS 101 539-1(V1.1.1) (2013). https://www.etsi.org/deliver/etsi_ts/101500_101599/10153901/01.01.01_60/ts_10153901v010101p.pdf. Retrieved January 2019.

[3]. https://trimis.ec.europa.eu/sites/default/files/project/documents/20130118_141143_85509_1-2-04_Flament.pdf. Retrieved January 2019.

[4] CIVIS project. http://www.civisproject.eu/images/Project-deliverable/civis-final-report.pdf. Retrieved January 2019

[5] SAFESPOT Project. http://www.safespot-eu.org/. Retrieved January 2019

[6] COOPERS Project. https://cordis.europa.eu/project/rcn/79301/factsheet/en. Retrieved January 2019

[7] SeVeCOM Project. https://www.sevecom.eu/. Retrieved January 2019

[8] COMesafety Project. https://cordis.europa.eu/project/rcn/80584/factsheet/en. Retrieved January 2019

[9] INTERSAFE-2 Project. https://cordis.europa.eu/project/rcn/87267/factsheet/en. Retrieved January 2019

[10] GeoNet Project. https://cordis.europa.eu/project/rcn/85551/factsheet/en. Retrieved January 2019.

[11] FOTsis Project. http://fotsis.com/ . Retrieved January 2019

[12] Shubham Shrivastava. (2019). " V2V vehicle safety communication." In Miucic, Radovan (ed.), Connected Vehicles Intelligent Transportation Systems, Springer Nature Switzerland AG., 117-155.

[13] https://www.eict.de/fileadmin/redakteure/Projekte/simTD/Deliverables/simTD-Deliverable-D21.2_Konsolidierter_Systemarchitekturentwurf.pdf . Retrieved January 2019.

[14] ETSI EN 302 637-3 (V1.2.0). (2014). https://www.etsi.org/deliver/etsi_en/302600_302699/30263703/01.02.01_30/en_30263703v010201v.pdf. Retrieved January 2019.

[15] Cargeo project. https://gforge.inria.fr/projects/cargeo6/. Retrieved March 2019.

[16] http://www.forlinx.net/products_detail/productId=81.html . Retrieved June 2019.

[17] https://github.com/CTU-IIG/802.11p-linux. Retrieved January 2019.

[18] https://www.etsi.org/deliver/etsi_ts/102800_102899/10289401/01.01.01_60/ts_10289401v010101p.pdf. Retrieved November 2018.