Demo: A Mobile Edge Computing-based Collision Avoidance System for Future Vehicular Networks

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***Abstract*—Mobile Edge Computing (MEC) is a key enabler for the deployment of vehicular use cases, as it guarantees low latency and high bandwidth requirements. In this paper, we propose a MEC-based cooperative Collision Avoidance (MECAV) system designed to anticipate the detection and localization of road hazards. It includes a Collision Avoidance service, allocated in the MEC infrastructure, which receives information of status and detected hazards from vehicles, processes this information, and selectively informs to each vehicle that either approaches to road hazards or to other vehicles. We have implemented a proof-of-concept of the MECAV system and we have validated its architecture and functionalities.**

***Index Terms*—V2X communication, Mobile Edge Computing, Collision Avoidance.**

I. INTRODUCTION

The automotive industry is currently undergoing important technological transformations. Vehicles are becoming more aware of their environment due to the integration of smart sensors, and their level of automation is rapidly increasing. In the near future, vehicles will exchange information with other vehicles (V2V), with the road infrastructure (V2I), with pedestrians (V2P) and with communication networks (V2N). This type of Vehicle-to-Everything (V2X) communication will allow vehicles to cooperate with each other and to extend their perception range beyond the capabilities of their own sensors, hence supporting new vehicular services that will improve road safety and increase traffic efficiency.

Vehicular services will pose stringent requirements to the underlying communication infrastructure. The next generation of communication networks (5G) will be an enabler for vehicular services [1], as it will guarantee ultra-low latency and ultra-high reliability under high mobility and densely connected scenarios. One of the pillars of 5G is Mobile Edge Computing (MEC), which brings processing, storage and networking capabilities closer to the network edge.

Even before 5G is rolled out, MEC can be considered a key driver towards the deployment of vehicular use cases [2]. This is due to the fact that MEC fulfills low latency and high bandwidth requirements, and it can be deployed at the roadside and at Mobile Network Operators' infrastructures [3]. As an example, the work in [4] proposed a MEC-based architecture for cellular V2N networks where MEC servers are integrated within the Radio Access Network and deployed between the core network and base stations. Recently, several field trials have demonstrated some vehicular use cases with the support of MEC [2]. For example, a MEC infrastructure has been deployed along 30 km of the A9 highway to demonstrate how vehicles can exchange information with an end-to-end latency below 20 ms using LTE [5]. The use cases deployed were cooperative passing assistant and electronic brake lights. Another field trial presented in [6] demonstrated the use case of assistance in road intersections.

Motivated by this context, we have developed a MEC-based cooperative Collision Avoidance (MECAV) system that allows to anticipate the detection and localization of road hazards in order to facilitate smooth vehicle reactions and to avoid hard braking and collisions. In the MECAV system, each vehicle sends its status information and detected hazards to the MEC infrastructure, which creates a distributed dynamic map with all collected information, and sends to each specific vehicle all the relevant data within its collision risk area. In this work, we describe the implementation and validation of the first proof-of-concept of the MECAV system.

II. MEC-BASED COOPERATIVE COLLISION AVOIDANCE

The architecture of the MECAV system is depicted in Figure 1. We consider a road where cellular base-stations (BS) are deployed along the road. Each BS provides wireless connectivity (V2N) to the vehicles within its coverage area. Each BS is connected to one MEC server with certain storage and computing resources, which allow the dynamic allocation of vehicular services and applications. MEC servers are interconnected through the core network in order to share information with each other. MEC servers also communicate with a Cloud data center to exchange information and maintain applications up-to-dated.

Each vehicle is equipped with a computer, a human machine interface (HMI), a cellular User Equipment (UE) and a set of sensors that detect dangerous events in their proximity, e.g., icy surfaces, unexpected manoeuvres of vehicles, traffic jams, emergency braking, vulnerable road users, etc. The application running in the vehicle's computer exchanges information via V2N with an application that runs in the MEC servers, named Collision Avoidance (CAV) service. In order to reduce latency, the vehicle application communicates with the closest MEC server, which is the one associated to the BS where the vehicle's UE is connected. The vehicle application sends

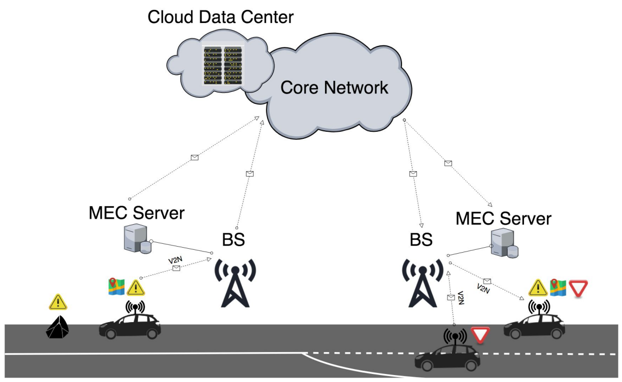

Figure 1: Architecture of the MEC-based cooperative Collision Avoidance system.

two types of ETSI ITS-G5 standard-compliant messages to the CAV service: periodical Cooperative Awareness Messages (CAM), which include the position, velocity and steering of the vehicle; and event-triggered Decentralized Environmental Notification Messages (DENM), which include the type and position of the detected event.

The functional architecture of the CAV service is depicted in Figure 2. The CAV service receives CAM and DENM messages transmitted by a group of vehicles; stores in a database the vehicles status and hazards information; checks distances between vehicles and hazards; and transmits CAM and DENM messages only to those vehicles that are either approaching to road hazards or to other vehicles. The vehicle application displays a Local Dynamic Map (LDM) on the HMI with the current position of the vehicle and warning messages with the information received in the CAM and DENM messages, i.e., detected events and vehicles within the collision risk area.

The CAV service predicts the radio handover of the UE by checking the vehicle's position within the BS coverage area. In case of handover, the CAV service indicates the destination MEC server to the vehicle application and the MEC servers initiate the relocation of application state information.

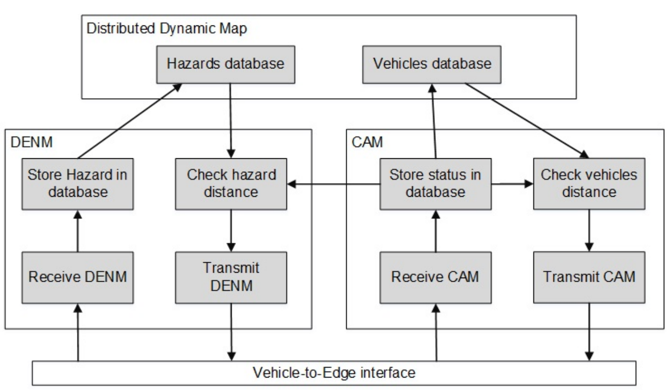

Figure 2: Architecture of the Collision Avoidance service.

III. System Validation

The field trial of the MECAV system will be deployed in the city of Barcelona. The infrastructure will consist of two LTE TDD Small Cells at 3.5 GHz and two MEC servers installed in street cabinets with direct fiber connectivity to the Small Cells. In this work, in order to facilitate our lab tests, we have implemented a proof-of-concept of the MECAV system using WiFi access points. We have used two vehicles equipped with a Linux computer connected to a GPS receiver and the vehicle's CAN bus via an OBD2 adapter. We have implemented a vehicle application based on OpenC2X [7]. It includes a graphical user interface with a Local Dynamic Map, allows triggering simulated events manually, and implements the ETSI ITS-G5 protocol stack. In the transport layer, we have extended OpenC2X with a new module that encapsulates over UDP the CAM and DENM messages exchanged between the vehicle application and the CAV service. We have implemented and validated the functionalities of the CAV service as well as the handover mechanism between MEC servers.

IV. Conclusions

In this paper, we have presented a new MEC-based cooperative Collision Avoidance (MECAV) system for vehicular networks. In the MECAV system, vehicles exchange CAM and DENM messages via V2N with a Collision Avoidance (CAV) service allocated in the MEC infrastructure. The CAV service processes all data received from vehicles (i.e., position of hazards, vehicles' velocity and position) and transmits to each vehicle only the relevant information within its collision risk area. We have implemented a proof-of-concept of the MECAV system composed of two vehicles, two WiFi access points, and the CAV service running on two MEC servers.

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References

[1] S. A. A. Shah *et al.*, "5G for Vehicular Communications," *IEEE Communications Magazine*, vol. 56, no. 1, pp. 111–117, January 2018.

[2] 5GAA, *Toward Fully Connected Vehicles: Edge Computing for Advanced Automotive Communications*. White Paper, 2017.

[3] F. Giust, V. Sciancalepore, D. Sabella, M. C. Filippou, S. Mangiante, W. Featherstone, and D. Munaretto, "Multi-Access Edge Computing: The Driver Behind the Wheel of 5G-Connected Cars," *IEEE Communications Standards Magazine*, vol. 2, no. 3, pp. 66–73, SEPTEMBER 2018.

[4] L. Li, Y. Li, and R. Hou, "A Novel Mobile Edge Computing-based Architecture for Future Cellular Vehicular Networks," in *IEEE Wireless Communications and Networking Conference (WCNC)*, March 2017, pp. 1–6.

[5] Continental, D. Telekom, F. ESK, and Nokia. (2015, November) Digital A9 Motorway Test bed. [Online]. Available: http://bit.ly/DT_AA

[6] Press release: Comba Telecom and ASTRI demonstrate Mobile Edge Computing system (MEC) with Vehicle-to-Everything (v2x) system prototype at Mobile World Congress 2017 in barcelona. [Online]. Available: http://bit.ly/5GAA_MEC

[7] F. Klingler *et al.*, "Field Testing Vehicular Networks using OpenC2X," in *15th ACM International Conference on Mobile Systems, Applications, and Services (MobiSys 2017), Poster Session*. Niagara Falls, NY: ACM, June 2017, pp. 178–178.