Experimental Set-up and Testing for Intersection Management based on Vehicle and Smart Road Connectivity

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***Abstract*—Experimenting with smart mobility means traveling on intelligent roads that allow for dialogue between vehicles and infrastructure. This involves the study and design of real-time and preventive intelligent systems for communication between road sensors and on-board vehicle devices. This paper aims to demonstrate the implementation of a communication scenario between V2X (Vehicle-to-Everything) connected transportation systems to facilitate the transit of an emergency vehicle (e.g., an ambulance, firefighters etc.) with the aim of managing the priority of vehicles at a smart intersection.**

I. Introduction

In 2022 alone, ISTAT (Istituto Nazionale di Statistica) reported that nearly 15% of accidents involve emergency vehicles, primarily in high-speed collisions with other vehicles [1]. On May 20th 2021, the Campania Region released a decree approving contributions to support investments to develop new intelligent solutions for the development of new technologies for the design and production of software environments and hardware devices that enable the communication between vehicles and the surrounding environment. Indeed, a research program called Borgo 4.0 has been promoted by ANFIA (Associazione Nationale Filiera Industria Automobilistica) with the involvement of a public-private partnership consisting of 54 companies, 3 public Research Centers, 5 Campanian Universities and the CNR (Consiglio Nazionale delle Ricerche). Borgo 4.0 platform accommodates the C-mobility project to create new intelligent solutions dedicated to vehicle-to-vehicle communications and the development of safety applications.

II. Methods

A. V2X communications

Safe and reliable data exchange is crucial for the development of Intelligent Transportation Systems (ITS) applications. Dedicated Short-Range Communication (DSRC) addresses this need by facilitating high-speed, secure communication between On-Board Units (OBUs) in vehicles and Roadside Units (RSUs) operating in the 5.9 GHz band. Specifically, DSRC protocol maintains robust data transfer even in challenging environments with obstacles or extreme weather making it a foundation for V2X applications in both densely populated and rural areas. In particular, the communication between vehicles and the surrounding environment can be divided into:

- Vehicle-to-Infrastructure (V2I), where the road infrastructure provides vehicles with a stream of information such as traffic, weather and road conditions, speed limits and accidents.
- Vehicle-to-Vehicle (V2V), allows real-time exchange of information between vehicles.
- Vehicle-to-Pedestrian (V2P), where vehicles use sensors to detect pedestrians, which gives collision warnings.
- Vehicle-to-Everything (V2X), which is the combination of all the above-mentioned types of connectivity.

The developed application represents a typical V2I communication scenario between an RSU and one or more OBUs near an intersection ensuringin the passage of the emergency vehicle in fastest and safest manner possible. In addition, European standard for vehicular communication is defined by ETSI (European Telecommunications Standards Institute) which defines a set of messages:

- CAM (Cooperative Awareness Message) that reports the status information of the ITS-G5 device (speed, position, etc.) and related attributes (dimensions, vehicle type, traffic role, etc.).
- DENM (Decentralised Environmental Notification Message) that signals the occurrence of specific events (accidents, congestion, etc.) and persists until the termination of the event.
- MAPEM (Map Extended Message) that informs the ITS-G5 stations within the DSRC range about the state of the relevant road segment.
- SPATEM (Signal Phase and Timing Extended Message) that indicates the status of one or more traffic lights at a relevant intersection.
- SREM (Signal Request Extended Message) is used to request the modification of a traffic light's following a request by an ITS-G5 station. The SSEM(Signal Status Extended Message) is the response message received by the station that previously made the request, indicating whether the request has been accepted or cancelled.

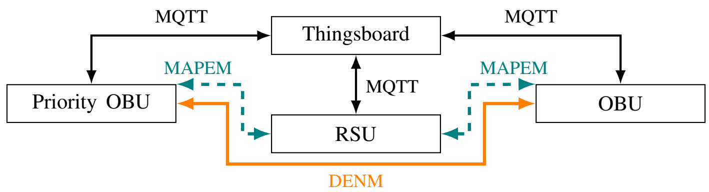

Fig. 1. V2I communication related to the scenario involving the prioritized crossing of an intersection by an emergency vehicle.

The scenario for managing priority at the intelligent intersection utilizes only MAPEM and DENM messages.

B. Road Side Units and On Board Units

An RSU is a DSRC transceiver mounted at the sides of the road or at pedestrian crossings [2]. The OBU is an electronic device installed in a vehicle capable of collecting vehicle-related data from sensors installed on the vehicle and traffic conditions communicating with smart roads [3]. Both devices are equipped with a DSRC transmission and reception system, a GPS receiver, memory, and a processor capable of running ITS applications for sending inter-vehicle messages. The hardware devices used for the test scenario are manufactured by Unex Technology Corporation [4].

III. Results

The experimentation took place at an intersection in Orta di Atella (CE)[1] whose satellite view is shown in Figure 2. It required the installation of an RSU on the roadside and two OBUs, respectively installed on the priority vehicle and on a common vehicle approaching the intersection. RSU is responsible for periodically transferring (every 100 ms) a MAPEM message containing the topological structure of the intersection described by lanes, which in turn are defined through a series of nodes: 5 lanes have been defined, each consisting of 3 nodes (Table I). OBUs within the DSRC range of RSU, by comparing their current position with that of the nodes defined in the received map, are able to determine in which lane they are located. The developed application allows emergency vehicles to send a notification to others common vehicles, both in the incoming lanes to a smart intersection. These vehicles receive an alert via an infotainment system and this persists until the emergency vehicle has crossed the intersection. The sending and receiving of alerts occur through DENM messages. Additionally, certain data such as lane and current position, are sent to the IoT platform Thingsboard via MQTT protocol. Figure 1 illustrates the diagram of devices and messages exchanged in the developed scenario.

[1]Located in 40.9789810, 14.2728627.

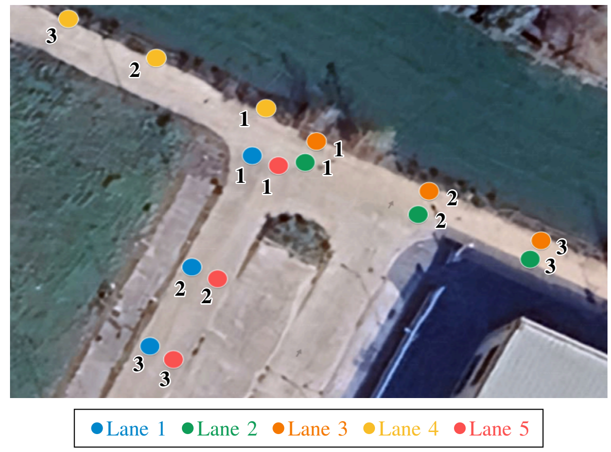

Fig. 2. Satellite image of the map transmitted by MAPEM messages. The numerical values reported represent the corresponding node.

IV. Discussion and Conclusion

V2X communications leveraging the DSRC communication protocol are essential for building safe roads and for more effective traffic management. Despite utilizing a dedicated channel, this protocol faces scalability issues: as message transmission frequency increases, the risk of message collisions escalates, limiting efficient error-free transmission to a few hundred vehicles within a communication range. Even with this limitation and the emergence of mobile network-based alternatives, DSRC remains the commercially available and mature solution for current ITS deployments. In fact, this paper present the design of a V2I communication scenario demonstrating how the use of a single notification can ensure the fastest and safest passage of the emergency vehicle, even in highly congested traffic situations. This scenario will be concretely implemented on Via Ronca in Lioni (AV) by July 2024, a non-light intersection. While designed for such cases, the scenario's adaptability allows for integration with traffic lights, enabling green wave prioritization for emergency vehicles.

TABLE I
Definition of nodes and lanes on the map transmitted by MAPEM messages

Node (Lat,Long)	Lane 1 (Incoming)	Lane 2 (Outgoing)	Lane 3 (Incoming)	Lane 4 (Outgoing)	Lane 5 (Outgoing)
1	40.9789481, 14.2728364	40.9789386, 14.2729264	40.9789687, 14.2729453	40.9790160, 14.2728600	40.9789340, 14.2728809
2	40.9787884, 14.2727343	40.9788639, 14.2731176	40.9788973, 14.2731363	40.9790880, 14.2726740	40.9787716,14.2727778
3	40.9786750, 14.27266314	40.9787998, 14.2733075	40.9788264, 14.2733260	40.9791450,14.2725250	40.9786561,14.2727031

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[4] Unex Technology Corporation. *Communication for a safer traffic - Unex Technology*. URL: https://unex.com.tw/en/.