5G MEC Architecture for Vulnerable Road Users Management Through Smart City Data Fusion

Enrico Rossini, Marcello Pietri, Roberto Cavicchioli, Marco Picone, Marco Mamei
University of Modena and Reggio Emilia
Reggio Emilia, Italy

Roberto Querio, Laura Colazzo and Roberto Procopio
Telecom Italia / TIM
Torino, Italy

ABSTRACT

Enhancing the safety of Vulnerable Road Users (VRUs) poses a significant research challenge in the context of connected mobility and a plethora of technological opportunities trying to balance efficiency and widespread applicability. This paper presents a demo focused on applying 5G Multi-Access Edge Computing (MEC) to address this challenge through the combination of commercial mobile devices, public cellular networks, and data fusion between vehicle positioning and city camera infrastructure. The demo showcases the designed system and its experimental evaluation in the Modena Automotive Smart Area (MASA) through the 5G MEC infrastructure of Telecom Italia (TIM) with the aim to build a secure and efficient connected mobility environment.

KEYWORDS

Smart City, Vulnerable Road Users, 5G, Edge Computing

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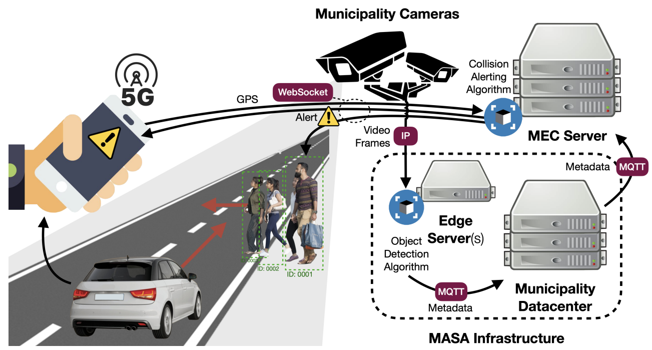

Figure 1: Schematic representation of the proposed demo's architectural design.

1 INTRODUCTION

Ensuring the safety of vulnerable road users (VRUs), such as pedestrians, cyclists, and motorcyclists, is a crucial aspect of intelligent mobility [1]. Traditional Vehicle-to-Everything (V2X) communication systems have been utilized for vehicle-infrastructure communication, but their reliance on short-range technologies limits their effectiveness in supporting a wide range of VRUs [2, 5]. In this paper, we focus on leveraging Multi-Access Edge Computing (MEC) solutions [6] and edge 5G connectivity to investigate new solutions to support VRUs in road safety. Our approach explores an alternative by utilizing public cellular connectivity, which offers a broader coverage and seamless connectivity to enable enhanced support for VRUs by integrating multiple data sources, including vehicle GPS positioning data and the Smart City smart camera infrastructure.

2 SYSTEM DESIGN

The designed system (schematically illustrated in Figure 1) operates within the context of the Modena Automotive Smart Area (MASA[1]), a dedicated testing area located in Modena, Italy, which provides a realistic environment for the development and testing of innovative automotive and mobility solutions and applications. MASA consists of real city streets augmented with intelligent mobility infrastructures and services. Video streams from smart cameras are processed by edge nodes for local video analysis, object detection (e.g., vehicles, buses, motorcycles, bicycles, and pedestrians), and generation of anonymous metadata adhering to privacy and

[1] https://www.automotivesmartarea.it

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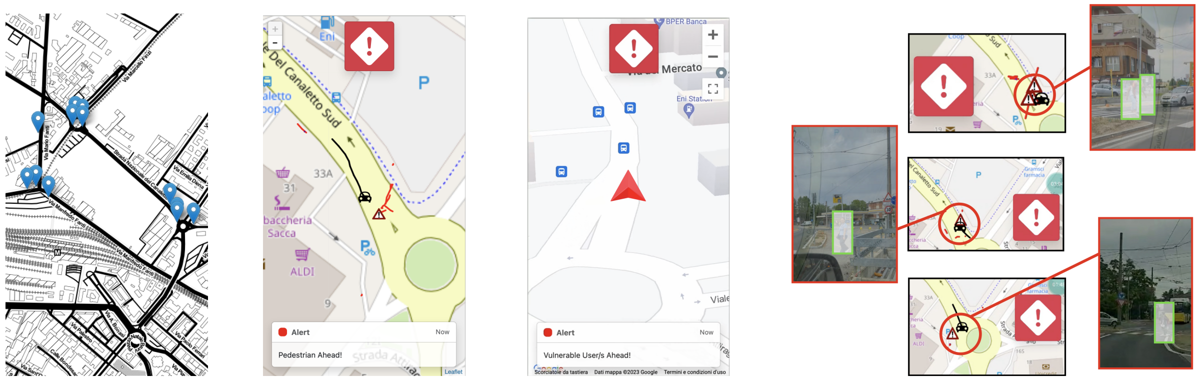

(a) (b) (c) (d)

Figure 2: (a) MASA Smart Cameras locations; (b) 3D interface with only relevant alerts; (c) The application showing both detected VRUs and alarms; (d) Experimental evaluation with detected VRUs and alerts.

GDPR [4] regulations. These metadata are transmitted to the MASA data center using the MQTT protocol [7] to build and maintain a centralized vision of city mobility patterns.

In this work, we extended the MASA infrastructure by integrating a new Multi-Access Edge Computing (MEC) layer. This MEC layer plays a crucial role in enabling real-time data integration from multiple sources and provides processing and analytics capabilities at the network edge. The MEC infrastructure, deployed in proximity to the MASA area by Telecom Italia (TIM) [9], ensures 5G network coverage with low latency and high bandwidth. MEC services are connected to the MASA infrastructure via MQTT, facilitating the exchange of mobility metadata. Additionally, bidirectional WebSocket communications[8] are established to allow connected devices (e.g., vehicles) to send GPS positioning data and receive alerts. The newly designed Intelligent Collision Alerting (ICA) algorithm is executed on the MEC layer, combining heterogeneous data to identify potential collision risks between vehicles and nearby VRUs. By comparing and estimating their directions based on received data, the algorithm detects potential collision scenarios and generates alerts for involved entities in the target geographic area.

3 DEMO DESCRIPTION

In order to showcase the capabilities of our approach, we designed and developed a web-based application that serves as a key component of our demo prototype. Installed on the driver's vehicle, this application is responsible for sending real-time GPS positioning data, visualizing a map with detected VRUs, and receiving alerts generated by the ICA algorithm running on the MEC infrastructure on the target geographic area illustrated in Figure 2(a). The web-based application utilizes modern web technologies to provide a user-friendly interface and seamless interaction with the system. It enables the driver to access important information and receive timely alerts regarding potential collision risks (videos have been made available [3]). Figure 2(b) and Figure 2(c) show two graphical versions of our app, the first is 2D but provides a dynamic mapping functionality to visualize the last seconds of traces for the tracked vehicle and VRUs in close proximity, and the second is designed more for the end user with fewer distractions. Even at this early stage of the designed system, the conducted field tests demonstrate the demo's capability to accurately identify and alert potential collisions, as shown in Figure 2(d). The successful low-latency combination of multiple city-level data in real-time, along with the notification system validates the effectiveness of the first stage of our approach in a real-world scenario enhancing driver awareness and contributing to collision prevention in smart city environments without requiring dedicated network infrastructure or onboard hardware.

4 CONCLUSIONS

In conclusion, this work presented a demo that combines 5G networks, MEC computational facilities to process and analyze diverse data sources to build a holistic view of the road environment and enable effective and intelligent management of VRUs. The demo showcased a solution capable of potentially reaching a wide number of users without the need for additional hardware and making the solution cost-effective and deployable in various environments. Future research and developments can further refine and expand upon the demonstrated capabilities, ensuring the continuous evolution and effectiveness of intelligent services to support vulnerable users in smart cities.

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