IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received 3 November 2023, accepted 11 December 2023, date of publication 15 December 2023,
date of current version 20 December 2023.

Digital Object Identifier 10.1109/ACCESS.2023.3343613

RESEARCH ARTICLE

# Federated Learning Enabled SDN for Routing Emergency Safety Messages (ESMs) in IoV Under 5G Environment

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**ABSTRACT** The emerging fifth-generation (5G) technology towards Internet of Vehicles (IoV) provides numerous advantages, such as lower levels of latency, stable link connections, and support for high mobility. However, avoiding vehicle collisions in IoV is a challenging task due to routing Emergency Safety Messages (ESMs) without strict delay and reliability requirements. To address this issue, we propose a novel intelligent Software-Defined Networking-based Collision Avoidance (SDNCA) framework assisted 5G. Primarily, SDNCA performs the first algorithm that accurately estimates the Risk Severity (RS) value for each vehicle via training the proposed Risk Severity-Artificial Neural Network (RS-ANN) model through the implementation of federated learning among vehicles. The SDNCA framework applies the second algorithm to achieve three main objectives. First, it calculates the Quality of Service (QoS) of the ESM based on RS, Vehicle Speed (VS), and Risk Distance (RD). Second, it dynamically allocates 5G network and computing resources ($gNB_{nr_i}$ and $gNB_{cr_i}$) for three Virtual Networks (VNs) based on QoS, RD, and VS. Third, it selects the best route (best gNB) for routing the ESMs from the Source Vehicle (SV) to the Destination Vehicle (DV). To ensure effective forwarding for each ESM, SDNCA deploys the third algorithm at the selected gNB to schedule the ESMs considering their priorities and configures the $gNB_{nr_i}$ and $gNB_{cr_i}$ based on the OpenFlow control message received from the SDN. The real-time simulation results demonstrate that the SDNCA framework achieves the ideal values of 17% Network Overhead (NO) and Computational Complexity (CC), a remarkable 0% Collision Rate (CR), 18 ms End-to-End (E2E) Delay, and 89%–90% Packet (ESM) Transmission Reliability (TR) compared with the existing related research.

**INDEX TERMS** 5G-IoV, beamforming, collision avoidance, emergency safety messages, federated learning, multi access edge computing, network function virtualization, software defined networking.

## I. INTRODUCTION

Technological transformations in automated vehicles are leading to vital changes in the transport systems and automotive industries due to their rapid proliferation on roads, contributing to increased safety and effectiveness [1], [2], [3]. Recently, the concept of the Internet of Vehicles (IoV) [4] has drawn significant attention as a promising approach to reduce traffic accidents, alleviate traffic congestion, and provide various convenient applications, such as autonomous driving, interactive entertainment, and real-time traffic information [5], [6].

The associate editor coordinating the review of this manuscript and approving it for publication was Sangsoon Lim.

The IoV connects hardware devices, network communication channels, and cloud platforms that allow connected vehicles, pedestrians, and intelligent units near the road to exchange information in real-time [7], [8], [9], [10]. Autonomous vehicles (AVs) are nearing commercialization and are expected to become dominant among various emerging vehicles in the future [11], [12]. Wireless communication technologies, specifically vehicular communications such as Vehicle-to-Everything (V2X) [13], along with existing vehicle-sensing capabilities [14], provide support for enhanced safety applications, thereby enabling AVs for safer autonomous driving [15]. The important supporting technologies of artificial intelligence (AI) [16] and fifth-generation (5G) networks [17], [18] in IoV technology are