SHORT-PAPER

# V2X Messaging with CoAP and EdgeX for Probabilistic Risk-Aware Coordination in Mixed Urban Traffic

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# POSTER: V2X Messaging with CoAP and EdgeX for Probabilistic Risk-Aware Coordination in Mixed Urban Traffic

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## Abstract

This article presents a standards-based architecture for V2X communication using CoAP and EdgeX Foundry. By mapping ETSI ITS messages to CoAP, the system enables efficient risk alerting at the edge. An inference module illustrates the architecture's extensibility, and the simulation confirms responsiveness and scalability under mixed traffic conditions.

## CCS Concepts

• **Networks** → *Cloud computing*; • **Information systems** → **Sensor networks**; • **Applied computing** → **Transportation**.

## Keywords

V2X, CoAP, EdgeX, ITS, CAM, DENM, Edge Computing, Multicast

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## 1 Introduction

Urban traffic is increasingly heterogeneous, with autonomous vehicles (AVs) and non-autonomous vehicles (non-AVs) sharing the road. In such mixed scenarios, anticipating risk and ensuring coordination is essential, yet current systems often fall short [3, 4, 9]. Events like sudden braking, pedestrian incursions, or lane deviations are challenging to manage without reliable, low-latency, cooperative event detection. Most vehicle-to-everything (V2X) systems rely on centralized, cloud-based architectures, resulting in high latency and limited scalability in distributed environments [6, 7]. Existing simulation frameworks often focus on communication stacks or high-level logic but lack integration with edge-native execution or constrained protocols. Even those that support cooperation rely on Dedicated Short-Range Communications (DSRC), ITS-G5, or Cellular V2X (C-V2X/5G), while overlooking application-layer protocols tailored for constrained environments. Although widely adopted in the Internet of Things (IoT), the Constrained Application Protocol (CoAP) remains underexplored in vehicular communication scenarios. This work explores its integration with EdgeX Foundry for edge-native V2X coordination messaging using CoAP. CoAP's features—UDP transport, multicast support, caching, and asynchronous semantics—are especially promising in these environments [5, 11, 12]. Standardized messages defined by the European Telecommunications Standards Institute (ETSI), such as Cooperative Awareness Messages (CAM) and Decentralized Environmental Notification Messages (DENM) [1], are mapped to CoAP methods and processed by a microservice-based inference engine at the edge via via EdgeX Foundry (edgexfoundry.org), an open source project. It enables multicast-compatible communication over UDP, replacing heavier stacks like MQTT or HTTP, and supports real-time risk alerting based on local and cooperative events—demonstrating how standardized ITS messaging can be efficiently handled via CoAP within edge-native platforms like EdgeX.

## 2 Approach and Methodology

To demonstrate the feasibility and benefits of using CoAP for vehicular communication, this work designed a standards-compliant architecture that maps ETSI ITS messages—specifically CAM and DENM [1], to CoAP methods and executes message-handling logic at the edge using EdgeX Foundry [2, 11]. This integration enables lightweight, multicast-capable message dissemination over UDP, contrasting with TCP-based stacks such as MQTT and HTTP, which remain predominant in many C-ITS deployments [8, 12]. While MQTT remains useful for stable, infrastructure-side links and higher-volume messages such as CPM, IVIM, or SPaT, CoAP is particularly suited for constrained vehicular nodes, where low overhead and rapid delivery are essential. In the proposed architecture, vehicles and RSUs transmit CAM and DENM messages via CoAP, supporting both request/response and Observe-based pub-sub semantics, while infrastructure elements may communicate via MQTT. All messages are received by EdgeX Device Services and routed through Core Data and Application Services to a Python-based microservice responsible for processing, classifying, and optionally propagating structured risk alerts. Leveraging CoAP's native multicast, caching, and compact binary encoding, the system ensures timely and bandwidth-efficient V2X communication, well aligned with edge and fog computing requirements [5]. To validate the architecture, this work implemented a proof-of-concept application that detects traffic anomalies such as emergency braking or intersection blockage, encodes them as DENM alerts, and multicasts them via CoAP to subscribed agents. These alerts follow ETSI message structures and are processed by receiving AVs or RSUs, enabling proactive behavioral adjustments. The alert

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dissemination logic includes severity classification (e.g., MINOR, CRITICAL), and full flow integration is shown in Figure 2. While the core contribution lies in demonstrating the integration of CoAP with EdgeX for standardized message handling at the edge, a basic probabilistic model is included to illustrate the framework's extensibility to local inference mechanisms. Traffic events are encoded in a discrete-time Markov chain, with transitions reflecting behaviors such as overtaking, stopping, or violations. Transition probabilities are updated based on observed traffic events, with a cooperation factor modulating the impact of AVs. Risk levels are estimated using Monte Carlo sampling over 100 iterations per cycle. Although simplified, this model provides a useful abstraction for assessing local traffic risk dynamics. If a critical threshold is exceeded, the system issues alerts through the EdgeX Notification subsystem, allowing AVs to adapt in near real-time.

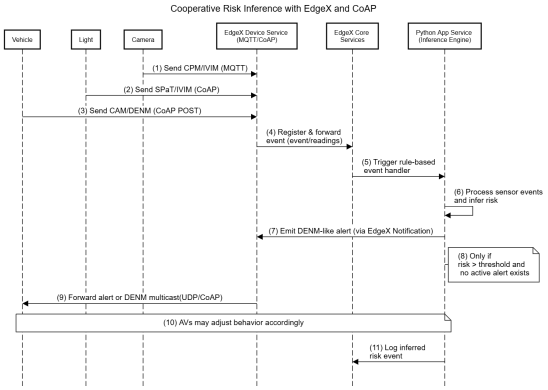

**Figure 1: Flow from message ingestion to alert multicast.**

## 3 Simulation and Evaluation Results

A simulation environment was designed to generate CAM and DENM messages from multiple agents. These messages are transmitted via CoAP over UDP and processed by EdgeX Foundry nodes deployed in Docker containers. CPM, IVIM, or SPaT are also transmitted through MQTT agents to simulate events from the infrastructure. The testbed includes both AV and non-AV entities, allowing assessment under varying levels of cooperation (i.e., different AV penetration rates). EdgeX ingests the messages, performs event classification, and issues risk alerts via its Notification subsystem, which multicasts messages to subscribed agents. The simulation consists of 6 camera-based sensors that capture and send messages CPM, IVIM with information on a number of people and cars detected with different states discovered, like crossing the road or a vehicle stopped on the sidewalk, and AV agents are created and removed dynamically. The scenario was run for two hours to retrieve results with events generated at 10 Hz, then the EdgeX nodes processed both AV and non-AV messages. Over 18 hours of continuous simulation data were collected during the experiment, capturing both cooperative and non-cooperative vehicular behaviors. The simulated environment maintained an average of 20 AVs and 55 non-AVs active at any time, with the cooperation factor varying dynamically, from fully cooperative (100% AVs) to fully non-cooperative (0% AVs) phases. This variability provided a realistic traffic profile, enabling the inference engine to adapt to changing AV-to-non-AV ratios. The system processed approximately 265,000 V2X messages, sustaining an average throughput of 5.09 messages per second. Traffic events were detected at a rate of 0.42 per second, resulting in 272 alerts (0.041/s). CoAP-based vehicular messages exhibited a mean processing latency of 0.65 ms, while infrastructure-originated MQTT messages (e.g., from cameras) showed 1.84 ms. These results underscore the benefits of CoAP's design, not directly comparing CoAP against DSRC or C-V2X, but focusing on its support for UDP transport, native multicast, and caching, which allows for low-latency and low-overhead dissemination of time-critical messages—even in variable traffic scenarios. Ensuring scalability and responsiveness in edge-based V2X deployments and confirming the system's ability to support time-sensitive communication and alerting under realistic traffic conditions. CoAP's compact encoding validates its suitability for scalable, edge-based V2X risk awareness. While not directly compared in this work, previous deployments have shown that edge-based V2X systems significantly outperform cloud-based alternatives in latency-sensitive scenarios, particularly when end-to-end responsiveness is critical [2, 10]. This illustrates the architecture's extensibility through a simple probabilistic model. Figure 2 presents a proof-of-concept result showing that increased AV cooperation reduces inferred risk of congestion and accidents over time. While not the core contribution, this result illustrates the architecture's potential to support real-time, data-driven applications beyond message routing, enabled by its integration of edge-native inference and alerting mechanisms. Overall, the results confirm the viability of CoAP-based ETSI ITS message handling over EdgeX Foundry for distributed vehicular coordination. The system demonstrated stable and efficient behavior across all test scenarios, reliably ingesting, processing, and multicasting alerts within the operational constraints typical of C-ITS environments.

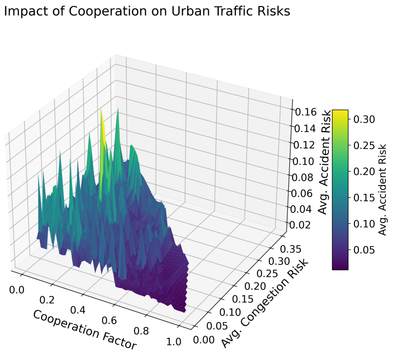

**Figure 2: Impact of cooperation ratio on inferred traffic risk.**

## 4 Conclusion

This work presented a standards-compliant architecture for V2X messaging and risk alerting using CoAP and EdgeX Foundry. By mapping ETSI ITS messages (CAM/DENM) to CoAP operations and processing them at the edge, the system supports multicast, low-latency communication and real-time alerting. Simulation results validate the framework's responsiveness and scalability. While the probabilistic layer is simplified, it demonstrates extensibility for edge-native inference. Future work includes enriching the model with contextual factors (e.g., weather, time) and testing on real-world 5G deployments.

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