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CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION

TRANSFORMING IDEAS INTO SOLUTIONS

Research Notes

Integrating the Wrong Way Driver Detection System into the Connected Vehicle to Everything (C-V2X) Environment

The project will deliver a scalable architecture compliant with ARC-IT 9.2, enabling future statewide guidance for implementing C-V2X-based Wrong Way Driver detection systems across California.

Traffic Operations

November 2025

Project Title: Integrating the Wrong Way Driver Detection System into Connected Vehicle to Everything (C-V2X) Environment

Task Number: 4457

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Task Manager:

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WHAT IS THE NEED?

Wrong Way Driving incidents are a significant traffic safety concern that can lead to catastrophic head-on collisions that result in severe injuries or fatalities. Despite advancements in traffic management and vehicle technologies, wrong-way driving remains a persistent challenge, particularly on high-speed roadways like highways and freeways. Traditional wrong way driver (WWD) detection systems have shown promise in preventing some incidents by alerting wrong-way drivers near off-ramps. However, these systems primarily address local challenges and often lack the capability to notify right-way drivers and law enforcement personnel across a broader area.

Caltrans has piloted an initial WWD detection system in District 11, which incorporates Light Detection and Ranging (LiDAR) for vehicle detection, AI-enabled cameras for event tracking, and visual and audible alerts for wrong-way drivers. While effective in mitigating some incidents, this system operates independently and is not integrated into a broader connected vehicle (CV) framework.

The emergence of Vehicle-to-Everything (V2X) technologies presents a transformative opportunity to enhance the capabilities of WWD detection systems. By integrating WWD detection with V2X infrastructure, notifications can be disseminated not only to wrong-way drivers but also to right-way drivers, law enforcement, and third-party navigation systems. This integration ensures timely communication, reducing notification latency and enabling proactive measures to prevent collisions. Furthermore, V2X-based systems align with the

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state's vision for Intelligent Transportation Systems (ITS) and the National ITS Architecture Reference (ARC-IT 9.2), promoting scalability and interoperability across California's roadways.

WHAT ARE WE DOING?

The primary objectives of this project are to enhance traffic safety by reducing the risks associated with WWD incidents and to develop a scalable, interoperable, and future-ready system that integrates seamlessly into California's transportation infrastructure. These objectives are structured to achieve immediate safety benefits while laying the groundwork for long-term, statewide adoption.

- Develop a Comprehensive C-V2X-based WWD Detection System:
  - Propose a generic architecture that supports integration with existing traffic management systems and future-ready Connected and Automated Vehicles (CAVs).
  - Design an end-to-end system that leverages advanced detection technologies (e.g., LiDAR, AI-enabled cameras) and edge computing for real-time processing.
  - Ensure interoperability through adherence to ARC-IT 9.2 and standard C-V2X messaging protocols, such as Basic Safety Messages (BSM), Traveler Information Messages (TIM), and Situation Data Sharing Messages (SDSM).
- Enhance Detection and Notification Capabilities:
  - Explore sensor options, including LiDAR, cameras, and multimodal sensor fusion, to optimize detection performance.
  - Develop geofencing strategies to reduce false alarms and target notifications to only impacted users.
  - Minimize notification latency to provide timely alerts to right-way drivers and law enforcement, enhancing their ability to respond effectively.
- Pilot and Validate the System in Caltrans District 11:
  - Integrate the new system design into an existing WWD detection system in District 11.
  - Conduct deployment testing with advanced sensors, RSUs, and potentially OBUs on experimental fleet vehicles.
  - Collect and analyze data to evaluate system effectiveness, reliability, and maintainability.
- Develop Statewide Implementation Guidance:
  - Compile insights from the pilot deployment into a comprehensive guidance document for Caltrans.
  - Address scalability, cost considerations, and best practices for deploying C-V2X-based WWD detection systems throughout California.
  - Ensure alignment with state and federal ITS architecture and regulatory frameworks.
- Deliver Measurable Safety Benefits:
  - Demonstrate the system's ability to reduce the likelihood of WWD incidents and associated collisions.
  - Provide timely and accurate notifications to reduce risks for right-way drivers, allowing them to safely maneuver away from danger.

WHAT IS OUR GOAL?

This project builds upon the existing WWD detection system in District 11, leveraging the latest advancements in AI, sensor fusion, and edge computing. The goal is to design, deploy, and evaluate a C-V2X-enabled WWD system that addresses current limitations and provides a roadmap for statewide implementation.

WHAT IS THE BENEFIT?

The elimination of wrong-way crashes is the goal. Wrong-way vehicles cannot be eliminated while people drive the vehicles. So, the next best thing is eliminating head-on collisions. Providing ample time to right-way drivers the opportunity to maneuver safely away from the wrong-way vehicle. It also provides time for law enforcement to respond. A timely warning to the driver is a benefit.

WHAT IS THE PROGRESS TO DATE?

July 1, 2025 – September 30, 2025

Key Activities and Progress

Kickoff and Planning:
The project officially launched with a kickoff meeting held on October 15, 2025. However, preparatory work began earlier in Q3 of 2025, including coordination with Caltrans District 11 and the UCLA Mobility Center of Excellence. The team reviewed the current WWD system and began outlining integration strategies with C-V2X infrastructure.

Task 1 – Concept of Operations and Requirements Development:
Work began on documenting the Concept of Operations for the integrated system. This included analyzing existing WWD systems for latency, detection accuracy, and integration limitations. The team also began defining high-level system requirements, including hardware (e.g., LiDAR, cameras, RSUs, OBUs) and software needs for edge processing, geofencing, and secure communications.

C-V2X Integration Strategy:
The team explored multiple communication channels for delivering WWD alerts, including direct PC5 (RSU to OBU), cellular V2X, and broader public alert systems such as Wireless Emergency Alerts (WEA 3.0). Each channel was evaluated for latency, coverage, and geofencing precision to determine the most effective use cases.

Architecture and Messaging Protocols:
Preliminary work began on designing a modular system architecture that supports standard C-V2X messaging protocols, including BSM, SDSM, and TIM. The architecture is being designed to support edge computing and integration with Caltrans' traffic management systems and third-party navigation platforms.

IMAGES

Image 1: Aerial view of the off-ramp, the WWD Detection System will be installed