U.S. Department of Transportation
Federal Highway Administration

Office of Safety and Operations
Research and Development

Cooperative Automation Driving System (C-ADS) with Road Weather Management (RWM) with a Lane Closure[1]

The Road Weather Management Program seeks to develop and promote effective tools to observe and predict the impacts of weather on the roads and to alleviate those impacts. The program pursues the following objectives:

- Develop a national, open observing system that promotes data sharing to support weather observation and forecasting and transportation operations.
- Develop resources and training methods to assist State and local partners in the deployment of weather management tools.
- Advance the state of the practice by developing proactive solutions and disseminating information on adverse weather.
- Foster a collaborative, comprehensive, and dedicated surface transportation weather research program.

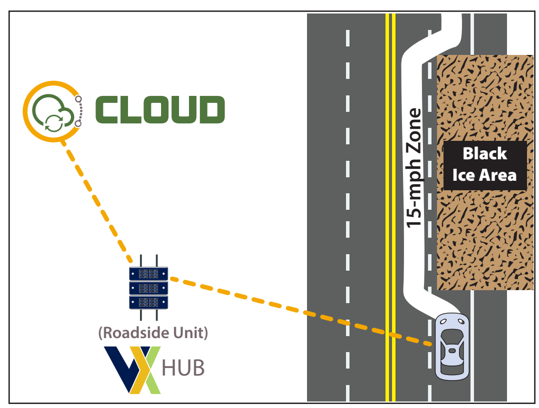
Source: Federal HIghway Administration (FHWA).

Figure 1. Photos. CARMA℠ [2] vehicle in icy road conditions.

This use case implementation focused on enabling lane closures around road locations affected by hazardous weather such as flooding or ice buildup. The Traffic Management Center systems, using CARMA Cloud℠ [3] would broadcast a traffic control message (TCM) to CARMA Platform℠ [4] to inform CARMA Platform of the flooded area and the need to change lanes or use an alternate route to avoid that location. The C-ADS vehicle[1] would use this information to plan a new path of travel, avoiding the lane closure and thus the hazardous area.

BENEFITS TO TRANSPORTATION

Vehicles and their passengers are at increased risk when operating in adverse weather due to low visibility and roadway surface changes such as flooding. These situations pose similar limitations for both human drivers and automated vehicles, though the extent of the limitations varies based on the sensor suite in use. Road operators can publish weather information that affects travel using TCMs to C-ADS-equipped vehicles[1] that request local route information with traffic control request messages. This system can help mitigate the effects of hazardous weather conditions for road users by providing early alerts and alternate travel paths and better equipping agencies' response and recovery efforts. This information may be passed through short-range communications or cellular networks. Figure 2 shows a vehicle communicating with a roadside unit (RSU) to avoid a road area with black ice.



Source: FHWA.
V2X Hub = Vehicle-to-Everything Hub.[5]

Figure 2. Graphic. Road weather management simulation scenario.

EVALUATION OF THE CONCEPT

For road users to benefit from this technology in a real road-weather scenario, intelligent transportation infrastructure systems must be deployed at the site to enable the Traffic Management Center to broadcast messages required by C-ADS vehicles.[1]

Future next steps involve seeking collaboration with industry partners to determine best practices pertaining to the communication of alternative travel paths and lane closures for weather-related incidents, and to study the behavior of C-ADS vehicles[1] in these situations.

USE CASE ARCHITECTURE

CARMA Cloud[3] allows users to create traffic controls on road sections affected by hazardous weather using a satellite-based map. V2X Hub[5] receives traffic control requests from the C-ADS-equipped vehicle,[1] obtains relevant TCMs from CARMA Cloud, and can broadcast these TCMs to the C-ADS-equipped vehicle. The C-ADS-equipped vehicle can apply traffic controls from received TCMs to its high-definition map and adjust its path by changing lanes out of the closed lane. The C-ADS-equipped vehicle also reduces its speed to the advisory speed limit. After exiting the road region affected by hazardous weather, the C-ADS-equipped vehicle can change lanes back into its original lane and increase its speed back to the normal speed limit.

RESULTS AND LESSONS LEARNED

The use case was successfully demonstrated and tested at Summit Point Circuit in Summit Point, WV, with validation testing conducted by the U.S. Department of Transportation Volpe National Transportation Systems Center. For verification and validation testing, the team used an RSU with a connection to CARMA Cloud[3] to broadcast TCMs to approaching vehicles to communicate an upcoming closed-lane section caused by weather. When received by a C-ADS vehicle,[1] the TCM could be used to update the vehicle's future path to change lanes and avoid the weather-related closed-lane section.

To evaluate the performance of the system, the project team collected data and calculated several performance metrics. The evaluation showed that most of the performance metrics were passed in all test runs, and the metrics that were not reliably passed still resulted in minimum viable performance. In general, the issues encountered during testing were due to vehicle control issues, including slower deceleration and acceleration rates performed by the vehicle than the rates stated in the desired performance metrics. Across all test runs, the software systems involved were able to correctly communicate information to each other. More specifically, the V2X Hub[5]-equipped RSU with a CARMA Cloud[3] connection was able to successfully broadcast TCMs, and the C-ADS-equipped vehicle[1] was able to receive and process the TCMs. This communication allowed the C-ADS-equipped vehicle to properly and safely navigate the road region affected by hazardous weather.

Standards

This technology meets the standards for the following as set by SAE International®:

- SAE J3216_202107™: *Taxonomy and Definitions for Terms Related to CDA for On-Road Motor Vehicles*.[1]
- SAE J3016_202104™: *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*.[6]

CONCLUSION

This technology's development highlighted the challenges of ensuring that separate data sources accurately describe the coordinate frames used to generate their data and receivers properly interpret the data. Developing an approach to address disparities between satellite-based maps and high definition maps from automated driving systems[6] is crucial for deployment. Future work could focus on developing more robust techniques for addressing spatial alignment issues or improving cybersecurity in CARMA Cloud[3]-to-CARMA Platform[4] connections.

Additionally, future work could further explore the use of cellular communications to provide approaching vehicles with more advanced notice of an upcoming geofence.

1 SAE International. 2020. *Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles*. SAE J3216_202005. Warrendale, PA: SAE International. https://www.sae.org/standards/content/j3216_202005/, last accessed October 19, 2020.

2 USDOT. n.d. "CARMA" (web page). https://its.dot.gov/cda, last accessed May 30, 2023.

3 FHWA. 2023. CARMA Cloud℠ (software). Version 4.3.0.

4 FHWA. n.d. "carma-platform" (software and configuration files in GitHub repository). https://github.com/usdot-fhwa-stol/carma-platform, last accessed April 12, 2023.

5 FHWA. n.d. "V2X-Hub" (software and configuration files in GitHub repository). https://github.com/usdot-fhwa-OPS/V2X-Hub, last accessed April 13, 2023.

6 SAE International. 2018. *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*. SAE J3016_201806. Warrendale, PA: SAE International. https://www.sae.org/standards/content/j3016_201806, last accessed May 30, 2023.

CARMA Cloud
https://github.com/usdot-fhwa-stol/carma-cloud

V2X Hub
https://github.com/usdot-fhwa-OPS/V2X-Hub

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For more information, please contact the CDA Program at CDA@dot.gov

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