2025 NOCoE
Transportation Technology Tournament

GenAI-Enpowered Smart Intersection Roadside Unit for Vulnerable Road User Protection

At the 2034 Winter Olympics In SLC

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Overview

This study presents the **S**mart **H**ybrid **I**ntersection **E**dge-based **L**LM **D**eployment for **R**oad**s**ide **U**nits (SHIELD-RSU), an advanced technological framework developed for the 2025 Transportation Technology Tournament (TTT) hosted jointly by the National Operations Center of Excellence (NOCoE), the Intelligent Transportation Systems (ITS) Joint Program Office (JPO), and the Institute of Transportation Engineers (ITE). SHIELD-RSU targets critical intersection safety challenges, especially for Vulnerable Road Users (VRUs) such as pedestrians and cyclists. Its deployment is driven by the anticipated transportation impacts of the 2034 Winter Olympic Games in Salt Lake City, which are expected to dramatically increase multimodal traffic volumes and strain existing infrastructure. Both the Utah Department of Transportation (UDOT) and Salt Lake City Transportation Division are seeking innovative solutions in response.

The severity of these challenges is amplified at urban intersections in downtown and nearby Olympic venues, which already pose high safety risks for VRUs. These risks escalate during large-scale events due to increased vehicular flows, adverse winter conditions, and the presence of unfamiliar visitors. While existing Vehicle-to-Everything (V2X) systems establish a baseline for connected intersection safety, they suffer from substantial limitations: high false-positive alert rates, limited accuracy in VRU trajectory prediction and localization, weak classification between micro-mobility users, and insufficient integration with adaptive signal control. These constraints highlight the need for more robust, intelligent safety mechanisms.

SHIELD-RSU introduces a new paradigm by leveraging Generative Artificial Intelligence (GenAI), specifically edge-deployed Large Language Models (LLMs), within a dense sensor fusion architecture. The system integrates LiDAR, radar, and high-resolution cameras mounted on RSUs functioning as edge computing nodes. These nodes perform real-time sensing, advanced algorithmic processing, and V2X communication to deliver safety-critical information to all road users. This framework shifts from reactive to predictive safety management, aiming to prevent collisions through early risk detection and intervention.

At its core, SHIELD-RSU operates on a low-latency data-processing pipeline that manages real-time intersection safety through sequential computational layers. It continuously ingests VRU localization data, connected vehicle kinematics, and 3D point clouds. After filtering spurious signals, sensor data is fused using Bayesian filtering and Convolutional Neural Networks (CNNs) for accurate object tracking and VRU classification. A Transformer-based AI model on the RSU's GPU generates multi-horizon trajectory forecasts using motion histories, HD maps, and real-time Signal Phase and Timing (SPaT) data. These predictions are fed into a time-to-collision (TTC) risk model, which activates adaptive signal controls and dispatches targeted alerts to users. The system also incorporates feedback mechanisms for ongoing optimization and scheduled weekly model retraining.

In essence, SHIELD-RSU marks a pivotal shift in intersection safety by overcoming the limitations of current V2X systems. By integrating edge-based LLMs with advanced multimodal sensors and real-time data processing enable a proactive, AI-driven approach to collision risk mitigation. Anchored by low-latency pipelines and Transformer-based trajectory prediction, the system significantly reduces collision risks, enhances VRU protection, and improves intersection efficiency. This scalable framework is purpose-built to address the complex safety demands of high-density traffic, harsh weather, and major international events such as the 2034 Winter Olympic Games in Salt Lake City.

Description of Problems

Salt Lake City, Utah, is preparing to host the 2034 Winter Olympic Games, an international event expected to generate a significant increase in pedestrian, cyclist, and vehicle traffic throughout the city. Past Olympic events have shown that such a surge in travel demands from both VRUs and vehicles can strain existing infrastructure, leading to a mismatch between supply and demand. This gap could result in higher risks of conflicts between VRUs and vehicles in surrounding communities. Additionally, adverse weather conditions, particularly during the winter season, can further exacerbate traffic safety concerns (shown as Figure 1). The 10-year historical data reveals that heavy snowfalls in the Salt Lake Valley can reach 297.18 mm [1], contributing to 23.4% of weather-related crashes [2][3]. Furthermore, travelers unfamiliar with the local road network and pavement conditions are more likely to be involved in crashes [4]. The lack of local driving experience can lead to sudden maneuvers, such as abrupt braking, acceleration, and turning, which can reduce the response time of other road users by 1.2 seconds [5]. In conclusion, the primary challenges contributing to increased collision risks between VRUs and vehicles during the Winter Olympics in Salt Lake City are the surge in travel demand versus infrastructure capacity, adverse weather conditions, and the lack of local driving experience.

To address these challenges and ensure readiness for the Winter Olympics, UDOT is leveraging $20 million in funding from USDOT to deploy innovative technologies aimed at saving lives and enhancing mobility across the state of Utah. Recently, a series of V2X systems, incorporating advanced sensors and V2X communication modules, have been implemented in Salt Lake City. These systems utilize LiDAR sensors installed as RSUs and employ 5.9 GHz radio frequencies to facilitate ultra-fast communication, less than 0.2 seconds, between RSUs and connected vehicles. With this smart system, UDOT is able to monitor traffic conditions in real-time and respond swiftly to accidents, significantly improving traffic safety and saving lives. However, the system is still in its early stages and faces some limitations in the following areas:

- **Perception Quality**: The existing LiDAR system faces challenges in dealing with environmental factors in complex intersection scenarios, leading to a high false positive rate of 54% in the preliminary evaluation. The noise of sensor data, occlusions, weather conditions, and intersection geometry can significantly impact the VRUs detection quality.
- **Prediction Ability:** The existing V2X system effectively reflects real-time information such as speed and location for both vehicles and VRUs. However, real-time awareness alone is insufficient for proactively alerting road users to potential hazards. Without predictive capabilities, the system cannot anticipate future conflicts or provide timely warnings. A forward-looking mechanism is essential to assist drivers and VRUs in avoiding accidents before they occur.
- **System Integration:** Current solutions rely on mobile applications to actively present warnings to users. However, limited adoption and penetration reduce their effectiveness at scale. To enable more proactive safety control, the system must integrate directly

with traffic signal infrastructure, allowing it to influence signal timing and intersection operations in real time to enforce safer conditions.

To bridge the current gap in intersection safety, this study proposes an advanced system, SHIELD-RSU, which leverages edge intelligence, sensor fusion, and real-time infrastructure coordination to enable proactive protection for road users. This integrated framework is designed to support timely, context-aware decision-making and enhance system responsiveness under dynamic urban conditions. The core methodology and technical components of this solution are detailed in the following sections.

Figure 1. Road Surface Condition During Winter in Salt Lake City

Study Area

To evaluate the effectiveness of SHIELD-RSU, the intersection of Redwood Road and 2100 South in Salt Lake City, illustrated in Figure 2, was selected as the primary study site. This four-way signalized intersection exemplifies the multifaceted challenges faced by VRUs in high-demand urban settings. It is surrounded by a diverse mix of land uses that generate substantial vehicle and pedestrian traffic throughout the day. Key activity centers include Dee's Family Restaurant to the northeast, the U.S. Post Office to the northwest, Les Schwab Tire Center to the southeast, and Burger King to the southwest, each contributing to a dynamic flow of drive-thru vehicles, short-term parking maneuvers, and pedestrian crossings. The intersection geometry includes three to four travel lanes in each direction, dual-turn lanes, and wide medians, resulting in crosswalk distances that exceed 70 to 80 feet. These extended crossing distances pose significant safety concerns for elderly individuals, children, and persons with disabilities, especially when signal timing is insufficient. High-speed turning movements, unpredictable jaywalking behavior, and the absence of adaptive signal control or real-time pedestrian warning systems further increase the complexity and risk. To support this evaluation, two LiDAR units and RSUs were installed at the corners of the intersection, streaming sensor data back in real time to enable continuous monitoring and response. These characteristics make the site an ideal testbed for deploying and validating a proactive safety framework capable of addressing real-world intersection hazards.

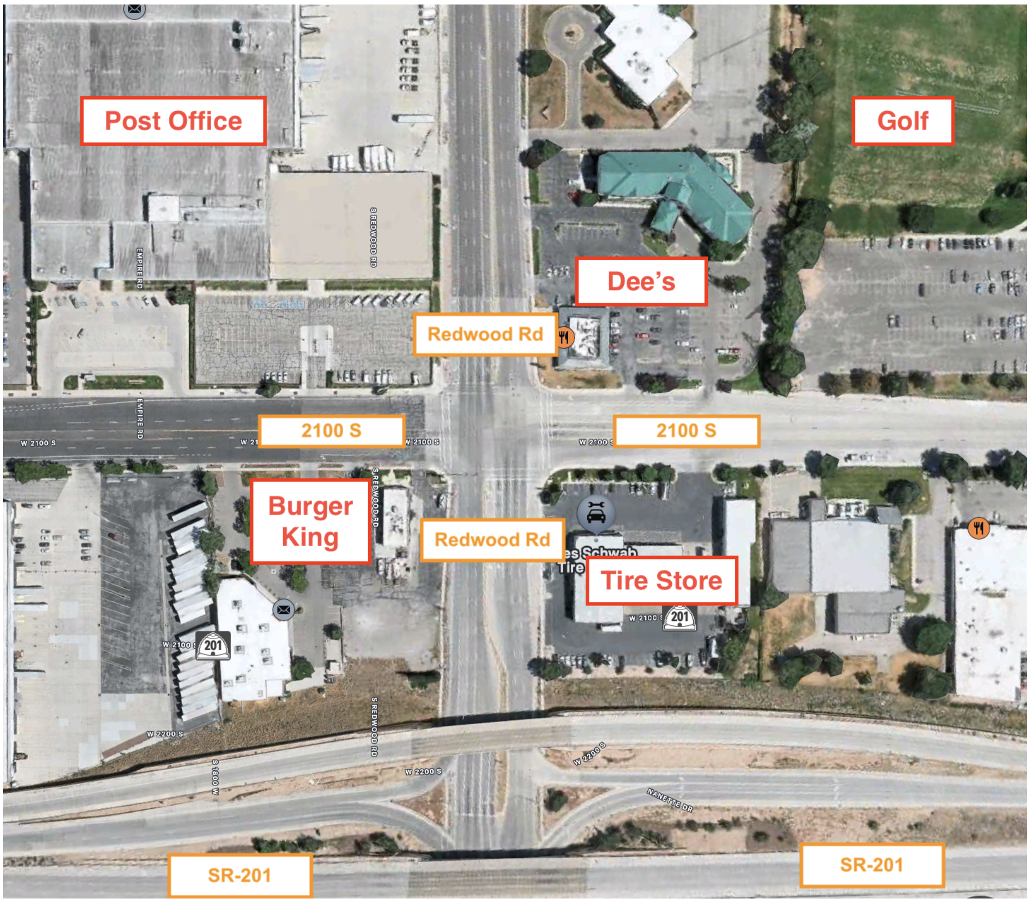

Figure 2. Study Area--Intersection of Redwood Rd & 2100 S

Methodology

The SHIELD-RSU system introduces a novel Generative AI powered framework for proactive intersection safety, operating entirely on the roadside through edge-deployed LLMs. As illustrated in Figure 3, the method integrates real-time ego vehicle data—location, speed, and heading—alongside live LiDAR detections of nearby objects, all streamed into the RSU.

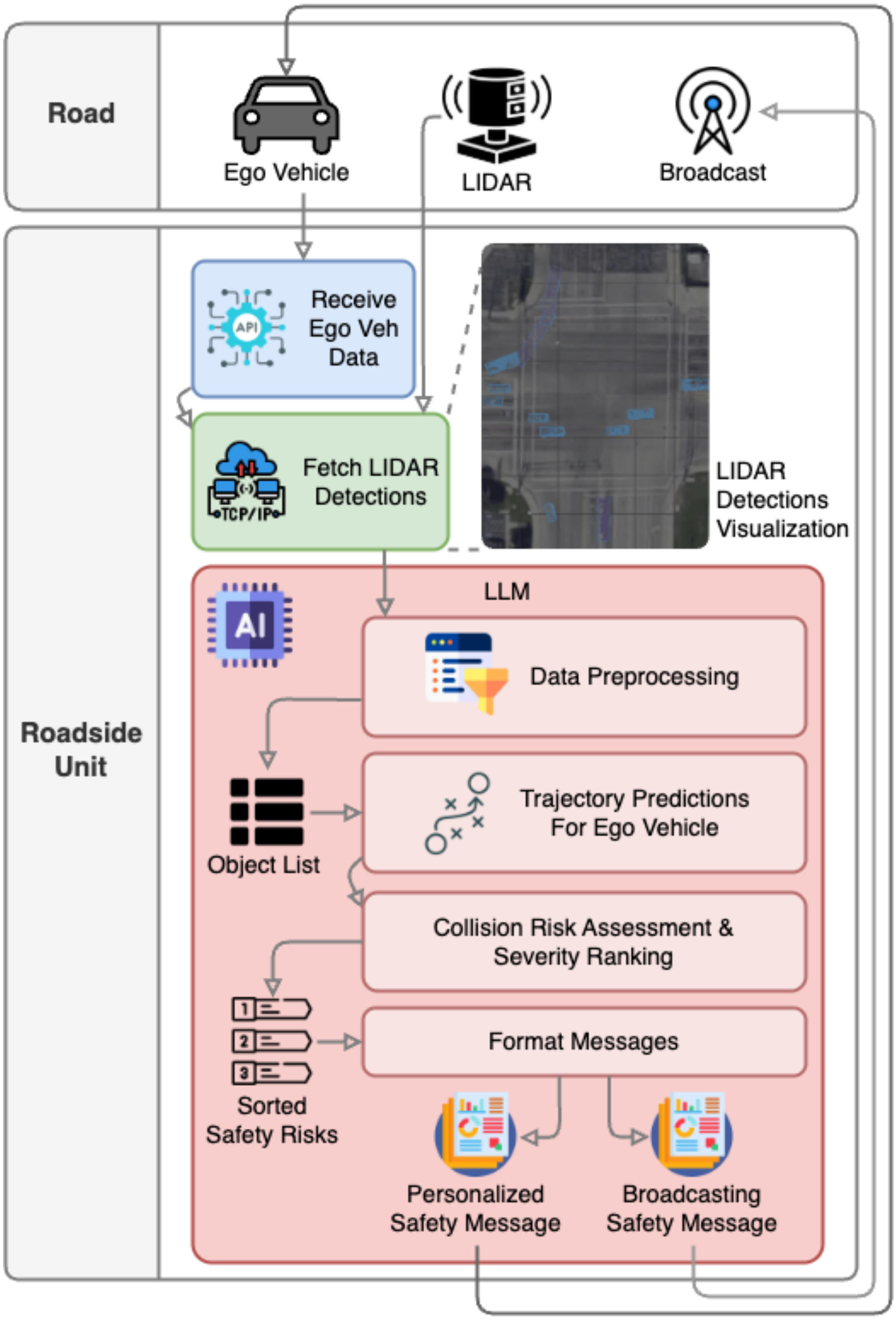

Figure 3. An Overview of SHIELD-RSU

The system workflow begins when VRUs are detected via LiDAR-based perception. The RSU initiates LLM-based processing, starting with data preprocessing to filter out false positives using contextual reasoning something that rule-based systems struggle to handle [6]. By understanding scene context, the LLM improves detection accuracy and system reliability.

Following this, the LLM performs trajectory prediction for the ego vehicle and surrounding VRUs. Unlike traditional models, the LLM handles multi-horizon long-range forecasting, such as 1, 3, 5, 10 seconds, and accommodates multimodal data such as camera and LiDAR simultaneously [7]. This allows it to make realistic and situation-aware predictions even when the VRU is ambiguously positioned, for example, between sidewalk and vehicle lane.

Next, the LLM assesses collision risk using TTC, relative speed, spatial overlap, and VRU vulnerability index. It can also adapt rankings contextually, recognizing ambulances in frame and reprioritizing risk rankings accordingly [8]. This enhances decision-making realism compared to conventional quantitative models.

Based on the risk ranking, the RSU generates two types of messages: personalized alerts tailored to the ego vehicle's context, and broadcast messages for nearby vehicles and VRUs that cannot directly communicate. The personalized messages reduce reaction time and cognitive load by offering user-specific content, which traditional systems cannot deliver. This is important because different road users may have distinct situational needs, such as varying speeds, maneuverability, or risk awareness, requiring alerts to be adapted accordingly. A driver approaching from a blind turn may benefit from a directional VRU alert, while a cyclist may need a warning about vehicle proximity. By tailoring messages, SHIELD-RSU ensures that each user receives the most relevant and actionable safety information for their perspective, environment, and role in traffic.

All processing occurs in real time on the RSU, which serves as a localized edge node for safety logic and V2X communication. In scenarios where vehicles or VRUs cannot send data, they still benefit from SHIELD-RSU through broadcasted alerts.

This unified framework streamlines AI reasoning, sensor fusion, and communication into a single deployable platform. It eliminates the need for multiple disjointed algorithms and supports continuous safety management with minimal maintenance, making it ideal for complex urban intersections.

Solution Architecture

The SHIELD-RSU system architecture is strategically designed to enhance intersection safety by integrating advanced sensing technologies, edge computing, and real-time communication protocols. This architecture clearly delineates responsibilities and functional elements within a comprehensive Intelligent Transportation Systems (ITS) framework, directly aligned with ARC-IT standards.

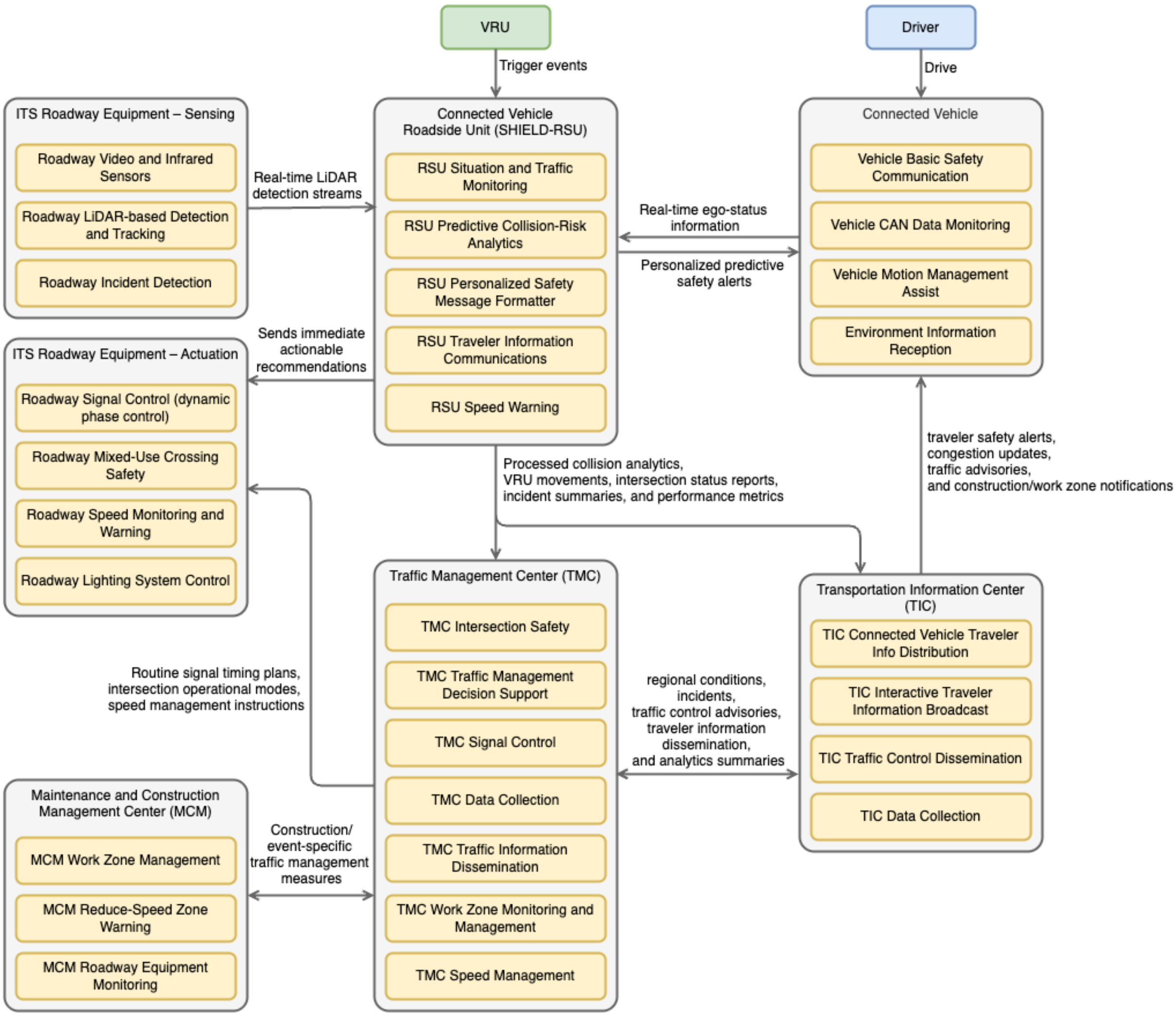

Figure 4. System Architecture

Table 1. Functional Description

Physical Object	Functional Objects	Primary Responsibilities
Connected Autonomous	Vehicle Basic Safety Communication (send/receive BSM)	Sends ego-status (loc, speed, heading); receives personalized

Vehicle (CAV/ego-vehicle)	Vehicle Situation Data Monitoring Vehicle Speed Management Assist Vehicle Traveler Information Reception	safety messages; updates driver alerts.
Personal Information Device (VRU)	Personal Traveler Information Reception Personal Interactive Traveler Information Trip Planning and Route Guidance	Provides personalized safety alerts and recommended actions to pedestrians and cyclists via smartphone/wearables.
Connected Vehicle Roadside Equipment (SHIELD-RSU)	RSE Situation and Traffic Monitoring (Object Detection Integration) RSE Predictive Collision-Risk Analytics (Edge LLM) *(New)* RSE Personalized Safety Message Formatter *(New)* RSE Traveler Information Communications RSE Speed Warning	Receives sensor data, performs trajectory predictions, collision risk assessment, severity ranking, formats personalized alerts, and communicates with vehicles/VRUs.
ITS Roadway Equipment – Sensing	Roadway Video and Infrared Sensors Roadway LiDAR-based Detection and Tracking Roadway Incident Detection	Provides high-resolution, real-time object detection data (vehicles, pedestrians, cyclists), continuously streams this data to SHIELD-RSU.
ITS Roadway Equipment – Actuation	Roadway Signal Control (dynamic phase control) Roadway Mixed-Use Crossing Safety Roadway Speed Monitoring and Warning	Dynamically manages intersection signals and lighting based on SHIELD-RSU predictive warnings; executes immediate signal adjustments for collision avoidance.

	Roadway Lighting System Control	
Traffic Management Center (TMC)	TMC Intersection Safety	Collects RSU performance data, collision events, and safety analytics; remotely manages intersection timings and policies; integrates with broader network-level management.
	TMC Traffic Management Decision Support	
	TMC Signal Control	
	TMC Data Collection	
	TMC Traffic Information Dissemination	
	TMC Work Zone Monitoring and Management *(optional)*	
	TMC Speed Management *(optional)*	
Transportation Information Center (TIC)	TIC Connected Vehicle Traveler Info Distribution	Aggregates and disseminates region-wide traveler information, broader traffic conditions, and safety advisories; communicates RSU/TMC-generated data regionally.
	TIC Interactive Traveler Information Broadcast	
	TIC Traffic Control Dissemination	
	TIC Data Collection	
Maintenance and Construction Management Center (MCM)*(optional)*	MCM Work Zone Management	Manages temporary changes in road configurations (e.g., construction or events), coordinates speed management and work zone safety.
	MCM Reduce-Speed Zone Warning	
	MCM Roadway Equipment Monitoring	
VRUs		Pedestrians, cyclists, and other VRUs interacting with the intersection.
Driver		Human operator of vehicle receiving safety messages via onboard HMI.

CAV plays a crucial role by sending real-time status information, including location, speed, and heading, and receiving personalized safety messages. These messages update driver alerts, significantly enhancing situational awareness. Personal Information Devices, such as smartphones or wearables, optionally provide personalized safety alerts and recommended actions to pedestrians and cyclists, improving their safety in the intersection environment.

At the core of the system, Connected Vehicle Roadside Equipment (SHIELD-RSU) integrates sensor data and performs advanced trajectory predictions using predictive collision-risk analytics powered by edge-based LLM. The SHIELD-RSU assesses collision risks, ranks severity, and formats personalized safety alerts for vehicles and VRUs. It communicates these alerts via real-time traveler information communication protocols, enhancing the reaction time and safety of all intersection users.

ITS Roadway Equipment dedicated to sensing—such as roadway video, infrared sensors, and LiDAR-based detection systems—provides continuous high-resolution, real-time object detection data for vehicles, pedestrians, and cyclists. This critical information stream is directed to the SHIELD-RSU for immediate analysis and decision-making.

Complementing the sensing technology, ITS Roadway Equipment dedicated to actuation dynamically manages intersection signals, mixed-use crossing safety mechanisms, roadway speed monitoring, warnings, and adaptive lighting systems. These systems respond directly to predictive warnings from the SHIELD-RSU, executing immediate signal and environmental adjustments to prevent collisions.

The Traffic Management Center (TMC) collects data regarding RSU performance, collision events, and overall safety analytics. It remotely manages intersection timings, operational policies, and integrates these intersection-level insights into broader network-level management strategies. The Transportation Information Center (TIC) aggregates and disseminates traveler information, traffic conditions, and regional safety advisories generated by the RSU and TMC. This comprehensive dissemination approach ensures travelers are consistently informed and advised on real-time conditions.

Optionally, the Maintenance and Construction Management Center (MCM) coordinates temporary traffic management measures, such as speed zone adjustments and roadway equipment monitoring, during construction or special events. This proactive management significantly improves safety during transitional and high-risk periods.

External actors, including pedestrians, cyclists (VRUs), and drivers, benefit directly from the personalized, timely, and actionable safety alerts provided by the SHIELD-RSU system. This ensures heightened situational awareness and improved safety outcomes for all intersection users.

To facilitate clarity and understanding, the visual representation of this architecture should distinctly highlight the SHIELD-RSU component, particularly emphasizing its innovative edge-based LLM inference and personalization capabilities. Physical objects should be organized into clear subsystems: Intersection Subsystem (SHIELD-RSU, ITS Roadway Equipment Sensing & Actuation), Management Subsystem (TMC, TIC, MCM), and Traveler/Vehicle Subsystem (Connected Vehicles, Personal Devices, Drivers, VRUs). Explicit arrows and clear labels should illustrate data flows, such as predictive safety messages, raw sensor data, and ego vehicle status, ensuring an intuitive and informative visual comprehension.

Field Test

To validate the effectiveness of the proposed SHIELD-RSU system in a real-world setting, the research team conducted a comprehensive field test at the study area. This effort was made possible through close collaboration with key stakeholders, including the UDOT, Salt Lake City Transportation Division, and the Wasatch Front Regional Council (WFRC). The research team also partnered with private-sector technology providers, including a commercial-grade LiDAR vendor and a V2X communication hardware supplier, to enable an integrated, sensor-to-communication deployment.

Figure 5. An Illustration of V2X Warning for an Aggressive Pedestrian Crossing the Street.

The test configuration involved installing two high-resolution LiDAR units at strategic corners of the intersection. These units continuously monitored vehicular and pedestrian activity across all approaches and relayed data in real time to RSUs for analysis (shown as Figure 6). The RSUs were equipped with an edge-based object detection algorithm and integrated with the V2X communication protocol to deliver predictive safety messages back to connected vehicles. This deployment allowed for real-time detection, risk assessment, and message dissemination using the LLM-based SHIELD-RSU framework.

The current platform is capable of detecting VRUs in real time and displaying their presence on the in-vehicle interface with both visual icons and audible alerts. As shown in Figure 5, a pedestrian crossing the intersection is detected and visualized on the connected vehicle's onboard display, prompting an immediate warning. Simultaneously, the system interfaces with the traffic signal controller to show the current signal phase and preview the upcoming phase for the specific lane group in which the vehicle is traveling, enhancing driver awareness and decision-making.

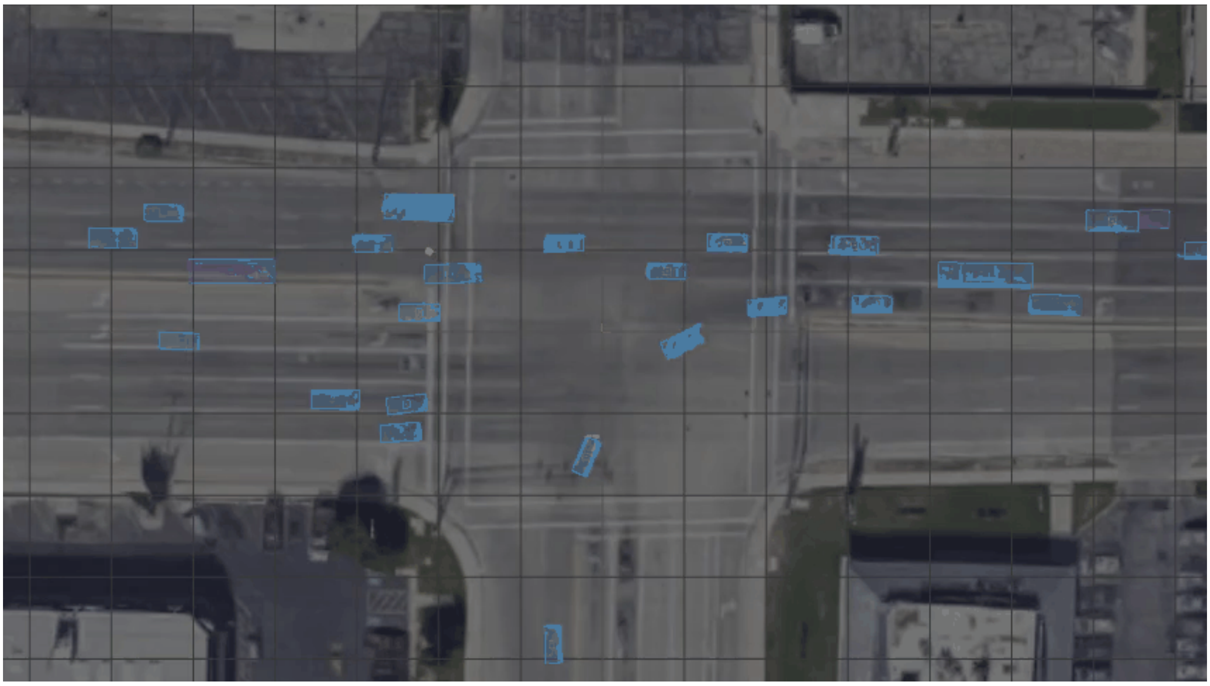

Figure 6. Real-time LiDAR Detection Results Visualization

Anticipated Impacts

The SHIELD-RSU system is a next-generation intersection safety solution that offers an efficient upgrade to conventional intersection systems by combining AI-powered sensing, predictive safety management, and real-time traffic optimization. It protects VRUs through proactive interventions while also ensuring smoother traffic movement and operational efficiency, particularly during large-scale events with high traffic demands. As a scalable and forward-compatible platform, SHIELD-RSU strengthens the resilience and responsiveness of urban transportation infrastructure, delivering various benefits for transportation agencies, road users, and other regional stakeholders.

Strategic Benefits

The SHIELD-RSU system directly supports the broader visions of the NOCoE [9] and the U.S. Department of Transportation (USDOT) [10] by advancing innovation, equity, and safety through operational excellence. In line with NOCoE's mission to empower the Transportation Systems Management and Operations (TSMO) community, SHIELD-RSU represents a forward-thinking deployment that transforms traditional signalized intersections into intelligent, adaptive safety zones. It also fulfills USDOT's core strategic goals—particularly in safety, transformation, and equity—by proactively preventing collisions, leveraging AI for smarter infrastructure, and addressing the needs of all road users, including underserved populations. As a replicable and scalable framework, SHIELD-RSU exemplifies how public-private collaboration and cutting-edge technology can strengthen national transportation systems, fostering resilience, inclusivity, and efficiency in preparation for both everyday operations and high-demand global events.

Safety Benefits

Intersections are consistently overrepresented in crash statistics, especially for VRUs [11]. SHIELD-RSU addresses this issue by enabling full-intersection monitoring and predictive safety interventions through real-time multi-sensor fusion and trajectory forecasting. Unlike conventional systems constrained to predefined detection zones, SHIELD-RSU dynamically captures VRUs across the entire intersection, including non-compliant behaviors such as jaywalking or late crossings. Its embedded neural models compute TTC metrics and trigger proactive measures, such as extending pedestrian phases or initiating emergency red-light activations, while issuing targeted alerts to both drivers and VRUs via V2X and roadside displays. These capabilities are particularly critical during the Winter Olympics, when unfamiliar road users increase the likelihood of unsafe behaviors. The system's ability to mitigate conflicts before they occur enhances safety for all road users, thereby supporting public confidence in event accessibility. For traffic operations centers and emergency services, SHIELD-RSU reduces the burden of manual monitoring while improving their ability to manage safety at high-risk intersections in real time.

Mobility Benefits

In addition to improved safety, SHIELD-RSU enhances intersection mobility through real-time adaptive signal control and V2X-enabled coordination. By analyzing live traffic conditions, the system dynamically adjusts signal timings to reflect actual demand, reducing delay, queue lengths, and spillbacks. This feature is valuable during Olympic-related surges, as it helps manage directional flows associated with venue ingress and egress, maintains regional throughput, and prevents localized congestion from propagating network-wide. V2X communication further smooths traffic flow by providing connected vehicles with Signal Phase and Timing (SPaT) and speed guidance, which minimizes unnecessary stops and travel time variability [12]. These improvements not only benefit commuters and transit operators navigating elevated demand but also reduce service disruptions for residents and local businesses during the event, supporting more reliable mobility throughout the host city. Additionally, this system can significantly help mitigate event-driven congestion, ensuring that the local transportation network remains functional even under heavy, unpredictable traffic conditions.

Pedestrian Accessibility Benefits

SHIELD-RSU enhances intersection accessibility by adapting to the diverse needs of pedestrians across different user groups, particularly those who may require additional time or space to cross safely, such as children, the elderly, and individuals with mobility challenges. By continuously monitoring the entire intersection and responding to real-time conditions, the system reduces dependence on static signal timing that may not accommodate varying user capabilities and behaviors. This functionality is important during the Winter Olympics, when large crowds heighten the demand for clear, timely, and adaptive crossing support. Through dynamic signal adjustments and personalized safety interventions, SHIELD-RSU fosters a more inclusive and accessible intersection environment for pedestrians.

Operational Benefits

From an operational perspective, SHIELD-RSU markedly reduces the management burden on transportation agencies by automating key functions of intersection monitoring and control. The system's autonomous incident detection, which can identify obstructions, stalled vehicles, and sensor anomalies, enables swift remedial actions or alerts to be issued without the need for extensive manual intervention. This streamlined operation is essential during high-intensity periods such as the Olympics, when rapid response and minimal disruptions are imperative. Additionally, the continuous logging of operational data and near-miss events provides a valuable resource for post-event analysis and long-term planning, ultimately leading to cost savings through data-informed optimization and reduced labor expenditures.

Other Benefits and Potential Risks

In addition to its primary functions, SHIELD-RSU delivers several secondary benefits. By improving traffic flow and reducing stop-and-go conditions, the system lowers vehicle idling and associated emissions [13], while its enhanced protection for pedestrians supports greater uptake of active transportation [14]. These outcomes advance broader sustainability objectives and reinforce Salt Lake City's commitment [15] to clean, efficient, and health-promoting urban mobility. Second, SHIELD-RSU enhances traffic reliability and provides actionable predictive analytics, resulting in cost savings for both transportation agencies and commercial stakeholders through reductions in crash-related expenses, emergency response needs, and productivity losses due to delays. Its modular architecture also supports scalable deployment, enabling the cost-effective expansion to additional intersections without requiring major reinvestments in physical infrastructure.

While the SHIELD-RSU system provides cutting-edge benefits, its performance relies on the accurate integration of multi-modal sensors and edge computing capabilities. One key challenge is ensuring the interoperability and seamless calibration of multi-sensor inputs in complex, dynamic environments. Furthermore, the effectiveness of predictive algorithms depends on the continuous quality of data input to avoid both false positives and missed detections. To address these risks, SHIELD-RSU can incorporate a robust feedback mechanism and a weekly retraining pipeline that continuously refines sensor fusion weights, trajectory prediction models, risk-scoring algorithms, and LLM prompt templates. These adaptive measures will help maintain high accuracy and reliability over time, enabling the system to evolve with changing operational conditions while maintaining its protective effectiveness under complex or adverse scenarios.

Conclusion

The anticipated spike in multimodal travel demand during the 2034 Winter Olympic Games in Salt Lake City introduces an urgent need to rethink intersection safety, particularly for vulnerable road users. In addition to the sheer volume of pedestrian, cyclist, and vehicle interactions, the presence of winter weather hazards and large numbers of unfamiliar drivers significantly elevates collision risks at critical urban intersections. While UDOT has begun deploying foundational V2X infrastructure with LiDAR-equipped RSUs and ultra-low-latency communication platforms, current systems are constrained by detection result quality, predictive capability, and integration with real-time traffic control mechanisms. These limitations hinder proactive safety intervention and fail to adequately support the dynamic, high-risk traffic scenarios expected during large-scale international events.

In response, this study introduces SHIELD-RSU—a next-generation, edge-intelligent intersection safety framework built to overcome the shortcomings of existing V2X deployments. The system integrates multimodal sensor inputs, including LiDAR, radar, and surveillance cameras, with a Transformer-based LLM deployed directly at the roadside. This architecture enables robust contextual reasoning, real-time object classification, and multi-horizon trajectory forecasting to assess and rank collision risks. Personalized and geo-fenced safety messages are delivered via V2X, while adaptive signal control is engaged to mitigate emerging hazards. SHIELD-RSU not only identifies conflicts but actively prevents them through intelligent, localized intervention.

Field tests conducted at a complex, high-volume intersection in Salt Lake City—through collaboration with UDOT, Salt Lake City Transportation Division, WSRC, and private-sector partners—demonstrated the operational readiness and real-world feasibility of the SHIELD-RSU system. The platform successfully detected vulnerable road users in real time, visualized their presence on connected vehicle displays, and issued timely audio warnings. It also synchronized with traffic signal infrastructure to present current and upcoming phase information to drivers, enabling safer and more informed decision-making. These tests confirmed the system's ability to integrate perception, prediction, and communication into a cohesive safety loop, reinforcing its suitability for deployment in high-demand scenarios such as the 2034 Winter Olympics.

Moving forward, continued refinement of sensor fusion algorithms and adaptive retraining pipelines will be essential to maintain system reliability under changing environmental and operational conditions. With its scalable architecture, SHIELD-RSU offers a resilient foundation for ITS, supporting both immediate safety enhancements and the long-term vision of safer, smarter, and more inclusive urban mobility.

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