Intelligent Transportation Systems Cluster (ARC-iTransportation)
Presentation in Joint Research Forum 2025

Research Title: Vehicle 2 Vehicle Communication Mechanisms in Infrastructure Less Environments using Temporal Projections

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Abstract

- Current Vehicle-to-Everything (V2X) systems are tailored to specific use cases and fail to adapt to dynamic mobility in heterogeneous environments.
- This results in poor connectivity and limited adaptability in both terrestrial networks and extraterrestrial missions (e.g., planetary exploration using rovers).
- This project aims to develop a unified, mobility-aware hybrid architecture that integrates cloud computing for infrastructure-based systems and ad hoc networking for infrastructure-less environments.
- This work supports Society 5.0 and advances the UN Sustainable Development Goals by fostering innovation (SDG 9) through Vehicle-to-Everything (V2X) technologies.

Background and Motivation

- An infrastructure-less environment (ILE) represents an area with no communication systems, such as cell towers and satellites. (See Figure 1)

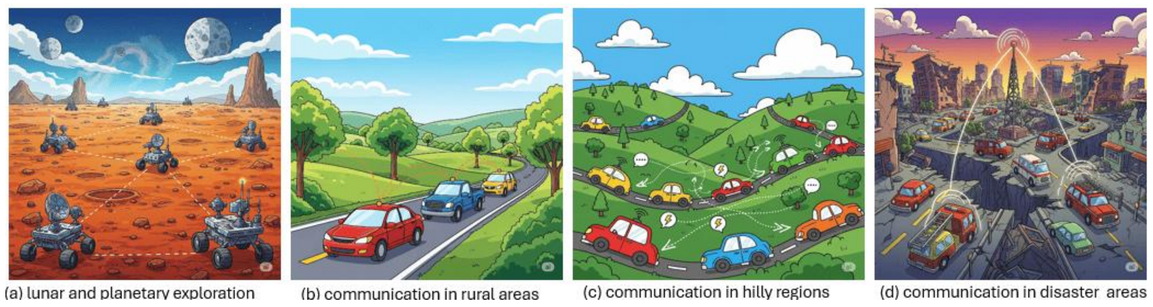

Figure 1: Applications of infrastructure-less environment (ILE)

- Vehicular Ad-Hoc Networks (VANETs) are crucial in establishing ad-hoc communication links between vehicles.
- Current VANET implementations of V2X systems [1,2] remain fragmented and application-specific, limiting adaptability, scalability, and resilience.
- Thus, limiting the mobility applications expanding from terrestrial networks—including urban transport, disaster response, and rural connectivity—to extraterrestrial environments such as lunar and planetary rover missions.

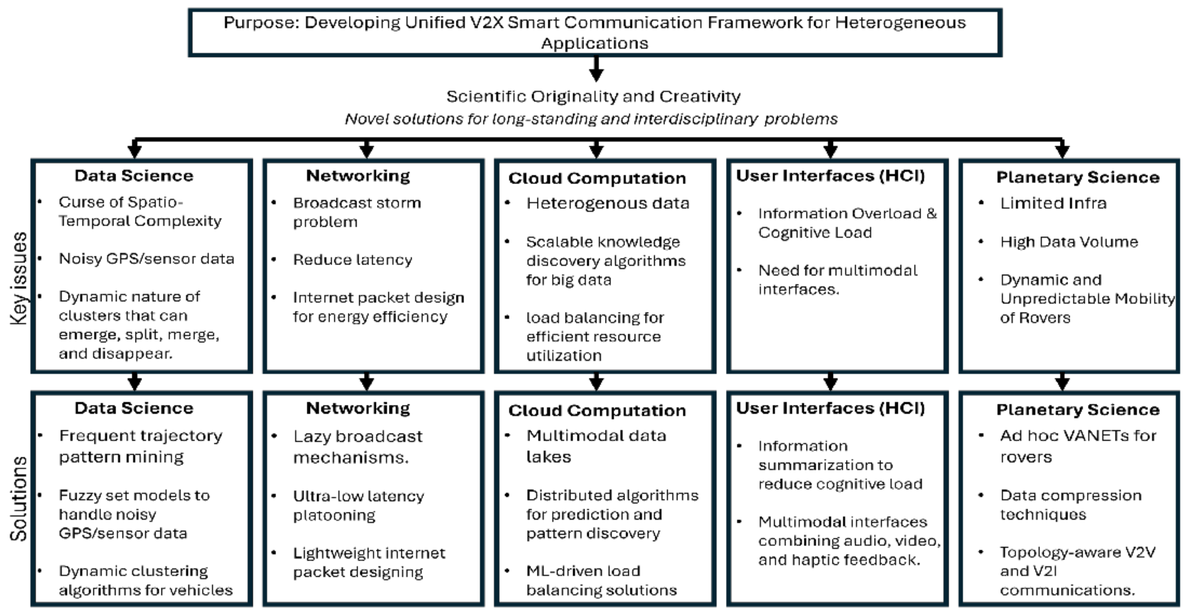

Figure 2: Key issues and solutions being investigated by the cluster members in their respective fields in the context of V2X and VANETs.

Research Contents (Methodology..)

- This project is to develop a unified, hybrid V2X framework that proactively adapts to dynamic mobility by integrating cloud scalability, ad hoc resilience, and predictive intelligence.
- Figure 3 shows the holistic view of the proposed system, where vehicles in a network are clustered based on their locations, and communication mechanisms are selected and implemented for each cluster individually depending on access to roadside units and cell towers.

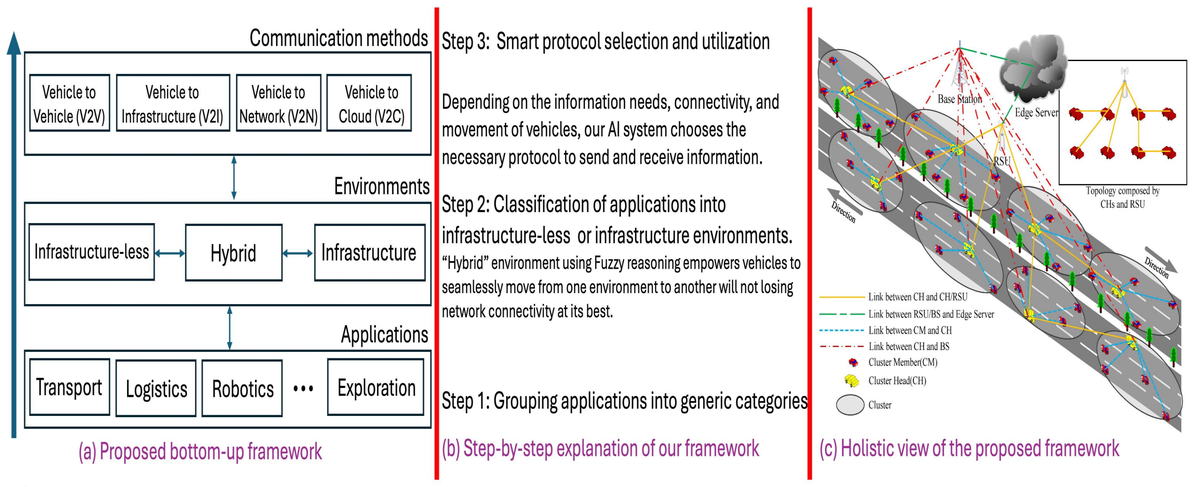

Figure 3: Proposed bottom-up framework to develop a unified communication protocol for V2X systems.

Experiments and Evaluation

Table 1: Experimental setup

Parameter	Value
Simulator	NS-3
Mobility Model	SUMO
Clustering Algorithms	K-means, MVC
Environment	3-Lane Highway
Network Size	20-100 vehicles
Performance Metrics	Queue Size, Packet Transmission, Packet - Delivery Ratio, Throughput, Average Delay,

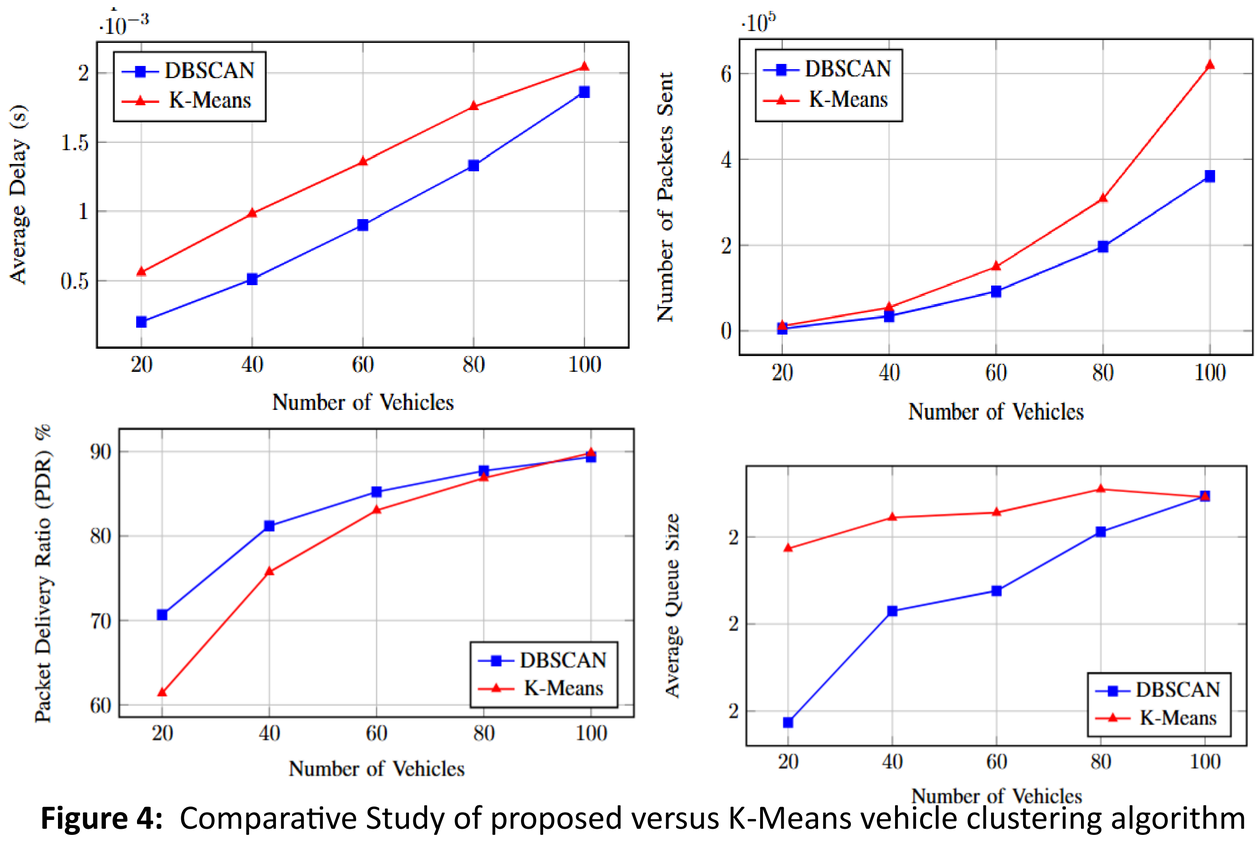

Figure 4: Comparative Study of proposed versus K-Means vehicle clustering algorithm in Network Performance

Simulation Case Study of V2X Covering Shinjuku Area

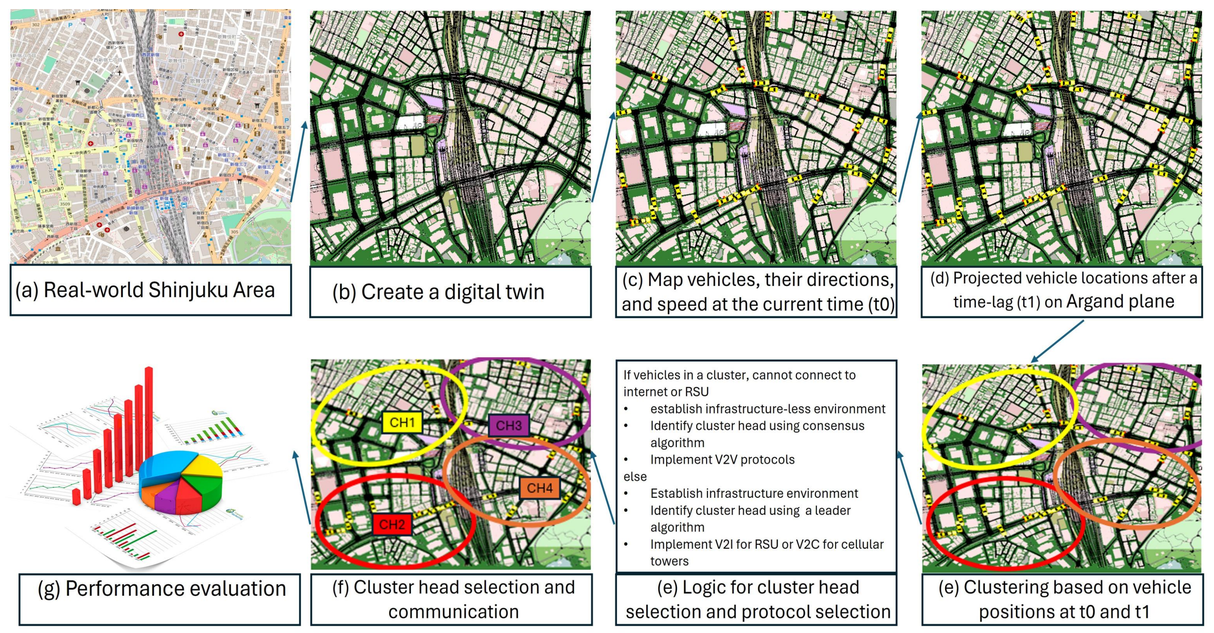

Figure 5: Simulated implementation of the proposed framework on the Shinjuku area.

Conclusions and Future Work

1. Proposed a novel fuzzy inspired high speed moving objects clustering algorithm for VANETS.
2. Experimental results demonstrate that the proposed algorithm is efficient and scales well for larger areas with 1000's of vehicles.
3. As a part of future work, we would like to cloud-based distributed clustering algorithm for fast moving objects and develop user interfaces to visualize them.

References

1. Boukhalfa, F., Hadded, M., & Alami, A. (2023). *Deep reinforcement learning algorithms for hybrid V2X communication: A benchmarking study*. arXiv. https://arxiv.org/abs/2310.03767
2. Khalid, I., Maglogiannis, V., Naudts, D., Shahid, A., & Moerman, I. (2024). *Optimizing hybrid V2X communication: An intelligent technology selection algorithm using 5G, C-V2X PC5, and DSRC*. Future Internet, 16(4), 107. https://doi.org/10.3390/fi16040107
3. NASA. (2023). *Extraterrestrial surface transport vehicles (rovers) OCHMO-TB-023*. NASA Technical Brief. https://www.nasa.gov/wp-content/uploads/2023/12/ochmo-tb-023-extraterrestrial-surface-transport-vehicles-rovers.pdf