**Problem Statement**

**(This problem statement is completely based only on communication of automated vehicles)**

Current advancements in 5G/6G-enabled communication for Connected and Automated Vehicles (CAVs) and Wireless Sensor Networks (WSNs) have demonstrated improved reliability, energy efficiency, and passenger comfort in simulations. However, these solutions lack real-world adaptability, scalability, and resilience under dynamic traffic, environmental, and network conditions. Existing systems do not integrate V2X reliability, energy-aware routing, and comfort-centric control into a unified framework. Furthermore, the absence of edge intelligence and fault-tolerant mechanisms hinders practical deployment. This project aims to develop an adaptive, intelligent communication framework for sustainable, real-time performance in mixed and constrained environments.

**Your Core Tasks (What You Need to Do)**

**🔹 1. Develop a Reliable V2X Communication Strategy**

* **Objective**: Enhance communication reliability between vehicles using 5G/6G.
* **Actions**:
  + Implement **priority-based groupcasting** or **IR-HARQ** (Incremental Redundancy Hybrid ARQ).
  + Simulate packet loss, delay, and throughput under different vehicle densities.
  + Compare with standard broadcast/unicast methods using real-world mobility patterns.

**🔹 2. Design a Comfort-Aware Control Model for Vehicles**

* **Objective**: Improve **passenger comfort** by reducing sudden acceleration/deceleration.
* **Actions**:
  + Use a **car-following model** (e.g., Full Velocity Difference model).
  + Introduce **multi-predecessor feedback control** (V2V-based).
  + Optimize feedback gains using control theory (e.g., transfer functions, stability analysis).
  + Simulate in a mixed traffic environment with both CAVs and non-CAVs.

**🔹 3. Implement Energy-Efficient Routing in Wireless Sensor Networks (WSNs)**

* **Objective**: Prolong WSN lifetime and reduce power usage in sensor-based data networks.
* **Actions**:
  + Use **Reinforcement Learning (RL)** to form clusters.
  + Apply **Residual Energy-based Cluster Head Selection**.
  + Optimize routing using **MOISA (Multi-Objective Improved Seagull Algorithm)**.
  + Simulate performance in NS-2 or equivalent (metrics: energy, throughput, delay).

**🔹 4. Integrate All Components into a Unified Framework**

* **Objective**: Create an intelligent system that connects CAV communication, passenger comfort, and WSN energy efficiency.
* **Actions**:
  + Use a modular approach (e.g., separate simulation environments for V2X, WSN, comfort model).
  + Share data across modules (e.g., WSN feedback to V2X for environmental awareness).
  + Optionally incorporate **Edge AI/Federated Learning** for adaptive decision-making.

**🔹 5. Validate Through Simulation**

* **Objective**: Demonstrate the effectiveness of your system.
* **Tools You Can Use**:
  + **SUMO** or **CARLA** for vehicle mobility simulations.
  + **NS-2 or NS-3** for network and routing simulations.
  + **MATLAB or Python** for algorithm development and control model tuning.

**🔹 6. Evaluate Key Performance Metrics**

Compare your integrated framework with existing solutions using metrics like:

* **Packet delivery ratio / throughput / delay (V2X & WSN)**
* **Network lifetime (WSN)**
* **Acceleration variance / stability index (comfort)**
* **Energy consumption (WSN)**
* **Reliability under packet loss or link failure (V2X)**

**📌 Final Deliverables**

1. **System Architecture Diagram**
2. **Simulation Models (Code & Setup)**
3. **Evaluation Report with Graphs/Comparisons**
4. **Final Integrated Framework Demonstration**
5. **Project Report (including literature review, methodology, results, and conclusion)**

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| **Aspect** | **Communication 1** | **Communication 3** |
| **Title** | Managing Connected Automated Vehicles in Mixed Traffic Considering Communication Reliability: a Platooning Strategy | Impact of Connected and Automated Vehicles on Passenger Comfort of Traffic Flow with Vehicle-to-vehicle Communications |
| **Main Idea** | Proposes a decentralized platooning strategy where CAVs follow a human-led vehicle to reduce complexity in mixed traffic. | Studies the effect of CAV feedback gains on passenger comfort in mixed traffic by optimizing stability using V2V. |
| **Key Findings** | Human-led (HL) platooning improves integration in mixed traffic.Communication reliability greatly affects platoon performance.Rule-based strategies significantly influence travel time and driving mode duration. | Optimal traffic flow stability via controlled feedback enhances passenger comfort.Stability improves with V2V-based feedback tuning in local platoons. |
| **Survey/Method Used** | Microsimulation of one-lane road with RSUs and CAVs.Evaluated under varying packet loss ratios (PLR).Rule-based decision models implemented for leader-follower roles. | Numerical simulations using car-following models (Full Velocity Difference model).Applied transfer function theory to evaluate traffic stability and comfort impact. |
| **Most Important/Common Point** | Communication reliability is crucial in real-world CAV deployment and directly impacts traffic efficiency and automation time. | Passenger comfort depends on minimizing acceleration/deceleration fluctuations, tied to optimized stability in traffic flow. |
| **Current Progress According to Paper** | Initial decentralized platooning concept tested in controlled simulation.Functional under reliable V2X conditions.Social acceptance model considered. | Proven that optimal feedback tuning can improve comfort metrics significantly.Model accommodates randomness and MDV-CAV mix. |
| **Literature Gaps Identified** | Lack of real-world testing on HL-based platooning.Insufficient consideration of non-CAV behavior impact on platoons.No scalability tested beyond one-lane roads. | Sparse literature on direct CAV impact on passenger comfort in mixed flow.Lack of unified comfort metrics.Limited application of feedback-based control in practical tests. |
| **Unresolved Problems / Future Work** | Need to extend to multilane or urban scenarios.Test with diverse traffic patterns and human driver behavior variability.More adaptive role-switching algorithms. | Apply model in dynamic real-world traffic with non-uniform platoon sizes.Study lateral vehicle behavior effects.Further explore impact under varying road and weather conditions. |

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| **Aspect** | **Communication 1** | **Communication 3** | **Communication 4** | **Communication 5** |
| **Title** | Managing Connected Automated Vehicles in Mixed Traffic Considering Communication Reliability: a Platooning Strategy | Impact of Connected and Automated Vehicles on Passenger Comfort of Traffic Flow with Vehicle-to-Vehicle Communications | Enhancing Reliability in 5G NR V2V Communications Through Priority-Based Groupcasting and IR-HARQ | Collaborative Energy-Efficient Routing Protocol for Sustainable Communication in 5G/6G Wireless Sensor Networks |
| **Main Idea** | Decentralized platooning where CAVs follow a human-led vehicle to simplify integration. | Optimizing passenger comfort by minimizing traffic instability via feedback gains in CAVs. | Enhancing 5G NR V2V communication reliability using groupcasting and IR-HARQ under delay/outage constraints. | Proposes collaborative routing protocol (CEEPR) using RL and MOISA to improve WSN energy efficiency. |
| **Key Findings** | HL platooning improves integration and mode duration; PLR impacts performance. | Controlled feedback improves stability and comfort in mixed traffic. | Throughput improved by 98% with IR-HARQ; groupcasting outperforms traditional broadcast. | Energy consumption reduced by 50%; extended network lifespan with better throughput. |
| **Survey/Method Used** | Microsimulation (1-lane road), RSUs, PLR scenarios, rule-based role switching. | Car-following simulations with FVD model; uses transfer function theory. | WiLabV2Xsim simulations, system-level analysis, 3GPP-compliant abstraction. | RL-based clustering, RE-based head selection, MOISA optimization, NS-2 simulation. |
| **Most Common/Important Point** | Communication reliability is key for effective platooning. | Comfort relies on stability optimization using feedback. | Reliable transmission in V2V depends on proper HARQ and casting strategies. | Adaptive routing and clustering is vital for sustainable WSNs in 5G/6G. |
| **Current Progress** | Simulation-based validation of platooning roles and effects under varying V2X. | Proven improvements in comfort and stability with V2V-tuned feedback gains. | Validated enhanced reliability and throughput in system-level tests. | Verified in NS-2 with strong performance over standard WSN routing. |
| **Literature Gaps** | No real-world trials; limited to one-lane, no multi-agent testing. | Sparse studies linking CAV control with passenger comfort in real-world setups. | Limited adaptability in changing traffic; no AI-integrated scheduling. | Lack of edge-AI and real-time sensing integration; resilience not well addressed. |
| **Unresolved Problems** | Expand to multilane/urban, include diverse driver behaviors, enhance role flexibility. | Apply to realistic mixed traffic, lateral motion effects, and adverse weather. | Evaluate in dense urban networks; develop AI-based adaptive retransmission. | Add federated learning, enhance security layers, validate with real WSN devices. |