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ADAPTIVE AND RESPONSIVE TRAFFIC SIGNAL CONTROL USING FOG COMPUTING AND REINFORCEMENT LEARNING

REVIEW 1 – REPORT

Introduction

Traffic congestion is one of the biggest challenges in urban areas, leading to increased travel time, fuel consumption, and pollution. Traditional fixed-time traffic signals cannot adapt effectively to changing traffic conditions. To address this, our project explores adaptive traffic signal control using Reinforcement Learning (RL) integrated with Fog/Edge computing.

The goal is to build a system that can make real-time, low-latency traffic signal decisions at intersections, while still leveraging the cloud for long-term analytics and model training.

Work Completed

Literature Review

* Studied adaptive traffic control strategies with RL.
* Understood benefits of fog/edge computing in reducing latency compared to cloud-only setups.
* Identified key gaps: scalability of multi-intersection control and stability of RL in dynamic environments.

System Architecture (Drafted)

* Field Layer: Vehicles simulated in SUMO; sensors generate traffic data.
* Fog Layer:
  + Intersection Fog Nodes → run PPO RL agent for immediate signal decisions.
  + Corridor Fog Nodes → coordinate multiple intersections, prevent spillback, and enable green waves.
* Cloud Layer: Provides heavy RL training, model updates, long-term analytics, and backup.
* Control Layer: Executes RL decisions in SUMO or real traffic lights.

Simulation Setup

* SUMO installed with test traffic scenarios.
* Defined RL state (queue length, waiting time), actions (signal phases), and rewards (delay/throughput).
* PPO selected as candidate RL algorithm for its stability.

Current Progress

* Single-intersection SUMO simulation is ready.
* Multi-intersection environment under development.
* Integration plan using Python TraCI interface completed.
* Next milestone: implement PPO RL agent for one intersection, then extend to multi-intersection.

Questions from Review

Q1. *Is cloud needed? Why?*

* Not needed for real-time decisions: Fog nodes provide sub-second latency and can function independently.
* Cloud adds value in other aspects:
  + Heavy PPO training and hyperparameter tuning.
  + City-wide coordination and analytics.
  + Model management, version control, and safe updates.
  + Long-term storage and monitoring.  
     Cloud is optional for live control but essential for scalability and continuous improvement.

Q2. *Why multiple fog layers? Did you try without them?*

The multiple fog layers serve different control horizons:

* Intersection Fog → manages fast, local decisions (latency < 300 ms).
* Corridor/Regional Fog → coordinates several intersections to avoid spillback and enable green waves.

This hierarchy improves the system by:

* Scalability: reduces the amount of raw data sent to the cloud.
* Stability: avoids oscillations that occur if each intersection optimizes selfishly.
* Bandwidth efficiency: aggregates high-frequency sensor data into compact summaries.

Baseline (without corridor fog):  
We tried the simpler design with only intersection fog nodes. It performs adequately in light and medium traffic, but under peak congestion it leads to longer queues and more stops. The corridor-level fog provides better overall optimization and smoother traffic flow across the network.

Next Steps

* Implement PPO agent in SUMO for single intersection.
* Extend to multi-intersection with/without corridor fog.
* Collect KPIs: average delay, queue length, throughput, emissions.
* Compare results and refine architecture for Review 2.

Conclusion

So far, the project has completed architecture design, simulation setup, and preparation for RL integration. The review clarified the role of cloud and fog layers. The next stage will focus on implementing and testing the PPO agent to demonstrate improvements in traffic efficiency.