**Project Title:** Cooperative Load-Aware Traffic Light Control System with Real-Time Simulation, Dashboard Visualization, and Emergency Override

**Project Summary:**

This project aims to design and implement a modern, intelligent traffic management system using machine learning, simulation, and real-time visualization. The core innovation lies in its ability to simulate a network of intersections that work cooperatively to manage traffic flow based on current vehicle load conditions, while providing a comprehensive web-based dashboard for monitoring, control, and emergency intervention.

Traditional traffic signal systems operate on fixed timers or simplistic sensor-based logic, which often fails to adapt to rapidly changing traffic patterns. This project introduces a multi-agent system where each intersection is modeled as an autonomous agent capable of detecting local traffic load, receiving congestion information from neighboring intersections, and dynamically adjusting its signal phases to reduce congestion and vehicle wait time.

The system uses crowdsourced or simulated traffic data to determine vehicle density and direction. Through the use of Reinforcement Learning (RL), each agent learns optimal timing strategies to improve overall network throughput. Furthermore, agents communicate using lightweight messaging (e.g., WebSocket or MQTT) to prevent overloading downstream intersections.

The traffic network and vehicle movement are simulated using SUMO (Simulation of Urban Mobility), with Python-based controllers interfacing through TraCI (Traffic Control Interface). The simulation data is exposed via a backend API (FastAPI or Flask), and the frontend Admin Dashboard is built using React.js with React-Leaflet for interactive map rendering.

**Key Features:**

1. **Load-Aware Adaptive Signal Control**
   * Each intersection adjusts its green light duration based on live traffic density.
   * Agents use ML models to learn and improve timing strategies over time.
2. **Cooperative Inter-Intersection Communication**
   * Intersections share congestion states.
   * Upstream signals delay green if downstream intersections are overloaded.
3. **Real-Time Simulation and Visualization**
   * SUMO simulates vehicle flow across a multi-intersection road network.
   * Real-time simulation data (queue lengths, light phases, traffic density) is visualized on a dynamic map.
4. **Interactive Admin Dashboard**
   * Displays live congestion levels on a color-coded map (green/yellow/red).
   * Real-time statistics panel: queue length, phase status, average wait time, system throughput.
   * Simulation controls: Start, pause, reset, and toggle between static and ML-based modes.
   * Log panel showing decision history and system responses.
5. **Emergency Override Feature**
   * Manual controls to override any intersection and force a green light for emergency vehicles.
   * Admin-controlled pedestrian and signal interruption simulation.

**Technology Stack:**

* **Simulation:** SUMO + TraCI
* **ML Framework:** Python, Stable-Baselines3 (for RL), or scikit-learn
* **Backend:** FastAPI / Flask
* **Frontend:** React.js + React-Leaflet / Mapbox for map visualization
* **Communication Protocols:** WebSocket or MQTT (optional for agent communication)
* **Data Visualization:** Chart.js, Recharts, or Dash (optional)

**Use Case:** This system can be deployed in smart cities to improve urban mobility, reduce congestion, and support emergency response routes. It also serves as an educational tool and simulation model for transportation planning and policy testing.

**Expected Outcomes:** - Increased traffic flow efficiency through coordinated signal control. - Reduction in vehicle idle times and travel delays. - Ability to monitor and intervene in real-time via a centralized admin interface. - Scalability across multiple intersections and adaptability to real-world deployment.

This system represents a leap forward in traffic signal control by fusing AI, simulation, and human-in-the-loop override capabilities in one robust platform.