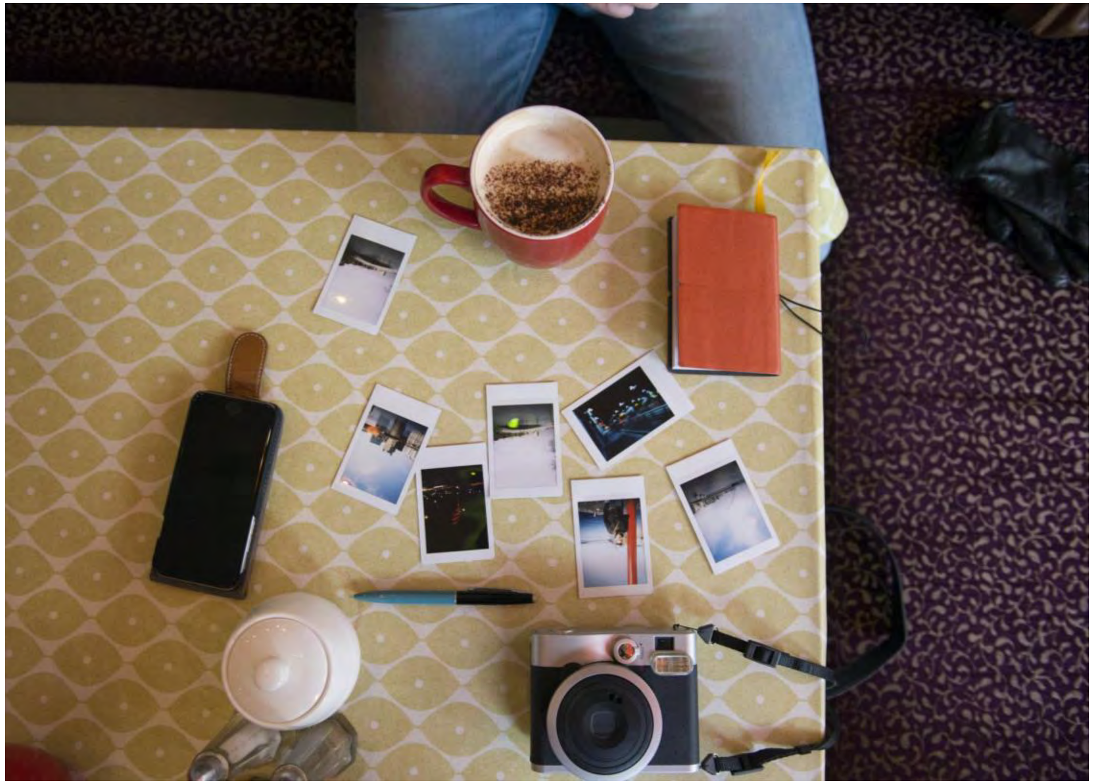
AI ON THE FAST LANE: SMART TRAFFIC SYSTEMS TO UNCLOG OUR CITIES

Revolutionizing urban transport with intelligent technology

Avraam Tolmidis

ABOUT ME: AVRAAM TOLMIDIS



- Working as Engineering Manager for 7 years
- Worked in various technical roles for the last 13 years in automotive, fintech and tech
- 4 years in automated driving
- Electrical and Computer Engineer, PhD in Multi-Objective Optimization, Degree in Education
- Mentoring, trying to grow computer engineers
- Teaching for 7 years, before switching to industry

AGENDA OVERVIEW

Traffic Management Systems – Current Challenges

Software Agents in Smart Traffic Systems

Required Infrastructure

Benefits of AI-Driven Traffic Management

TRAFFIC MANAGEMENT SYSTEMS – CURRENT CHALLENGES

URBAN TRAFFIC MANAGEMENT – A GROWING CHALLENGE

Increasing Congestion

Traffic congestion is rising in urban areas due to population growth and increased vehicle usage, leading to longer commute times.

Inadequate Infrastructure

Many cities struggle with outdated or insufficient infrastructure, making it difficult to manage rising traffic demands effectively.

Growing Number of Vehicles

The increase in the number of vehicles on the road poses significant challenges for urban traffic management systems.

Delayed Reaction to Traffic Events

Our systems are slow to react to events, need human interventions, that take time.

Result: Lost time, lost fuel, lost lives

WHAT IF TRAFFIC MANAGEMENT SYSTEMS COULD THINK?

What if every car and traffic light was an intelligent agent?

What if they could negotiate, adapt, and optimize in real time?

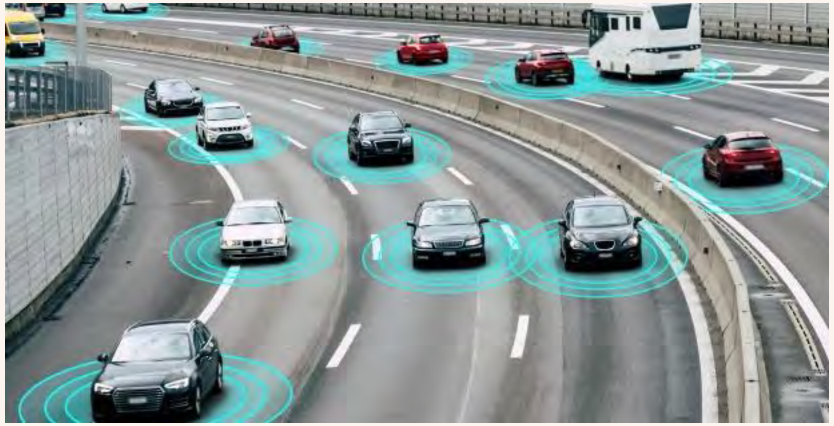
That's the idea behind decentralized traffic intelligence

SOFTWARE AGENTS IN SMART TRAFFIC SYSTEMS

ENTER THE AGENTS

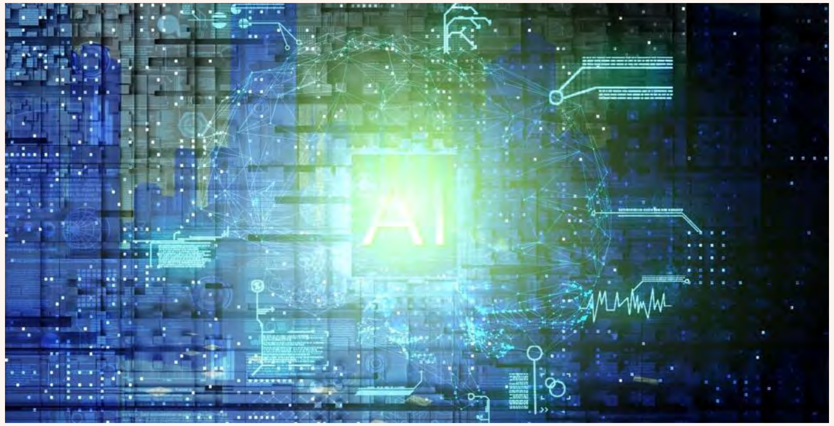
- Vehicles = Mobile agents
- Intersections = Stationary agents
- Each makes decisions based on local context
- More centralized optimizations and policies can be applied

THE AMOR SYSTEM



- AMOR = Adaptive Multi-objective Optimized Routing
- Agents optimize for time, distance, cost, emissions
- They 'bid' for road segments based on current value
- Routes evolve continuously as traffic changes

HIGH-LEVEL PROCESS



- A vehicle approaches a decision point (e.g., intersection).
- It requests potential next steps from nearby stationary agents.
- Each stationary agent calculates a bid (cost estimate) for using the road segments of a route it proposes, based on current data.
- The vehicle evaluates all bids using its weighted objective function.
- It selects the lowest-cost next step (best trade-off among its priorities).

BID-BASED NEGOTIATION (1)

- Vehicle agent :
  - sends route request to nearby stationary agents, plus weights for each objective to optimize
- Stationary agent:
  - accesses segment data for each objective - calculates / updates expected values for segments of potential routes if data is stale
  - Normalizes values for each segment
  - Calculates cost per segmentusing the weighted objective function:

$$cost = w\_time * time + w\_distance * dist + w\_cost * mon\_cost$$

- calculates possible routes

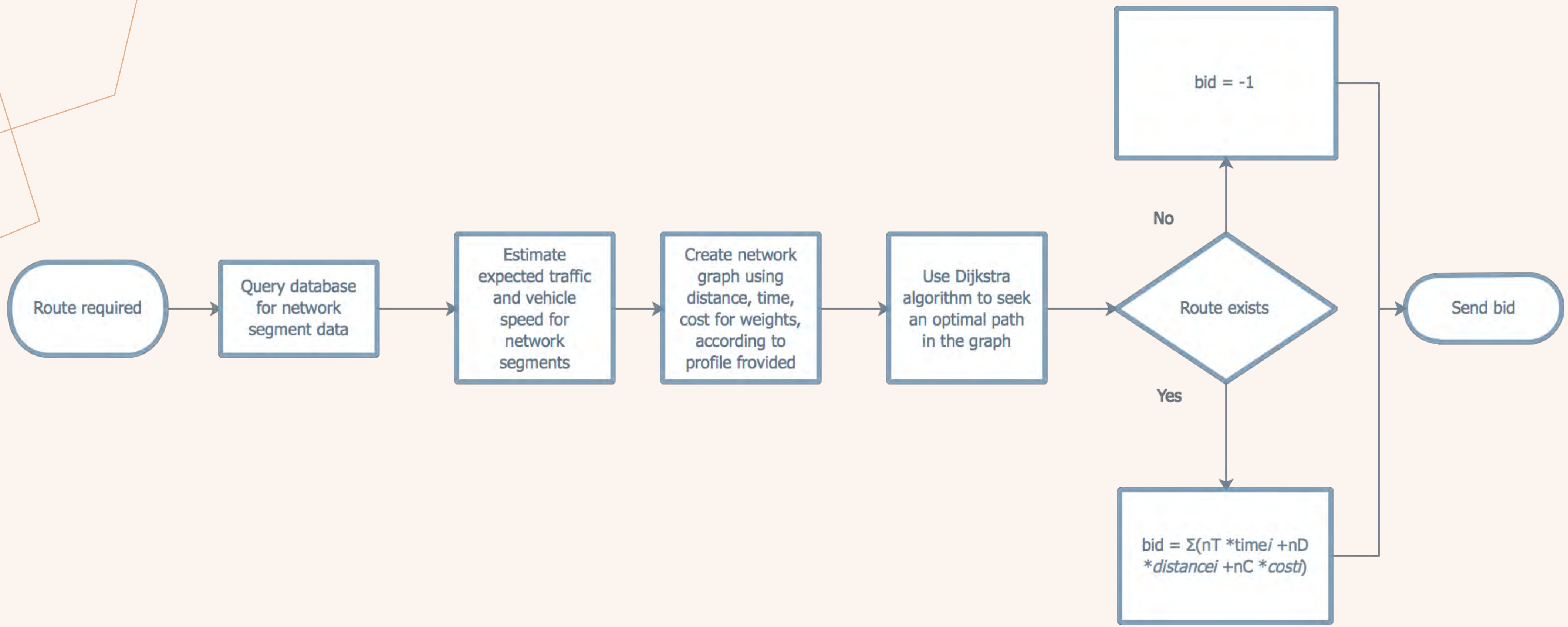
BID-BASED NEGOTIATION (2)

- Route cost: sum of segment costs.
- Stationary agent Bid: Cost of lowest route cost
- Vehicle selects and follows the initial segments of the lowest bid route

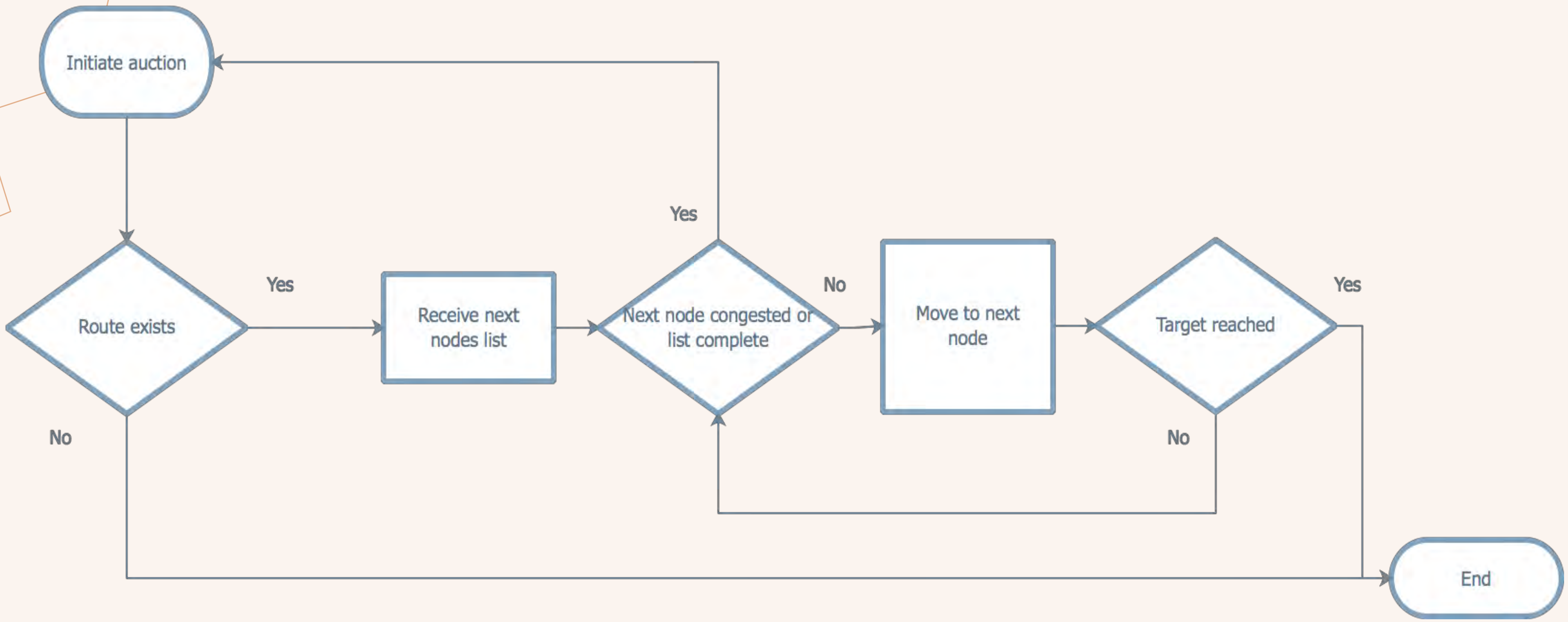
CONTINUOUS REPLANNING

- As the vehicle moves, it re-evaluates options every few steps.
- Conditions change (e.g., congestion, accidents) -> stationary agents suggest better alternatives.
- Allows for real-time rerouting and self-adaptation.

BID GENERATION PROCESS (3 OBJECTIVES)



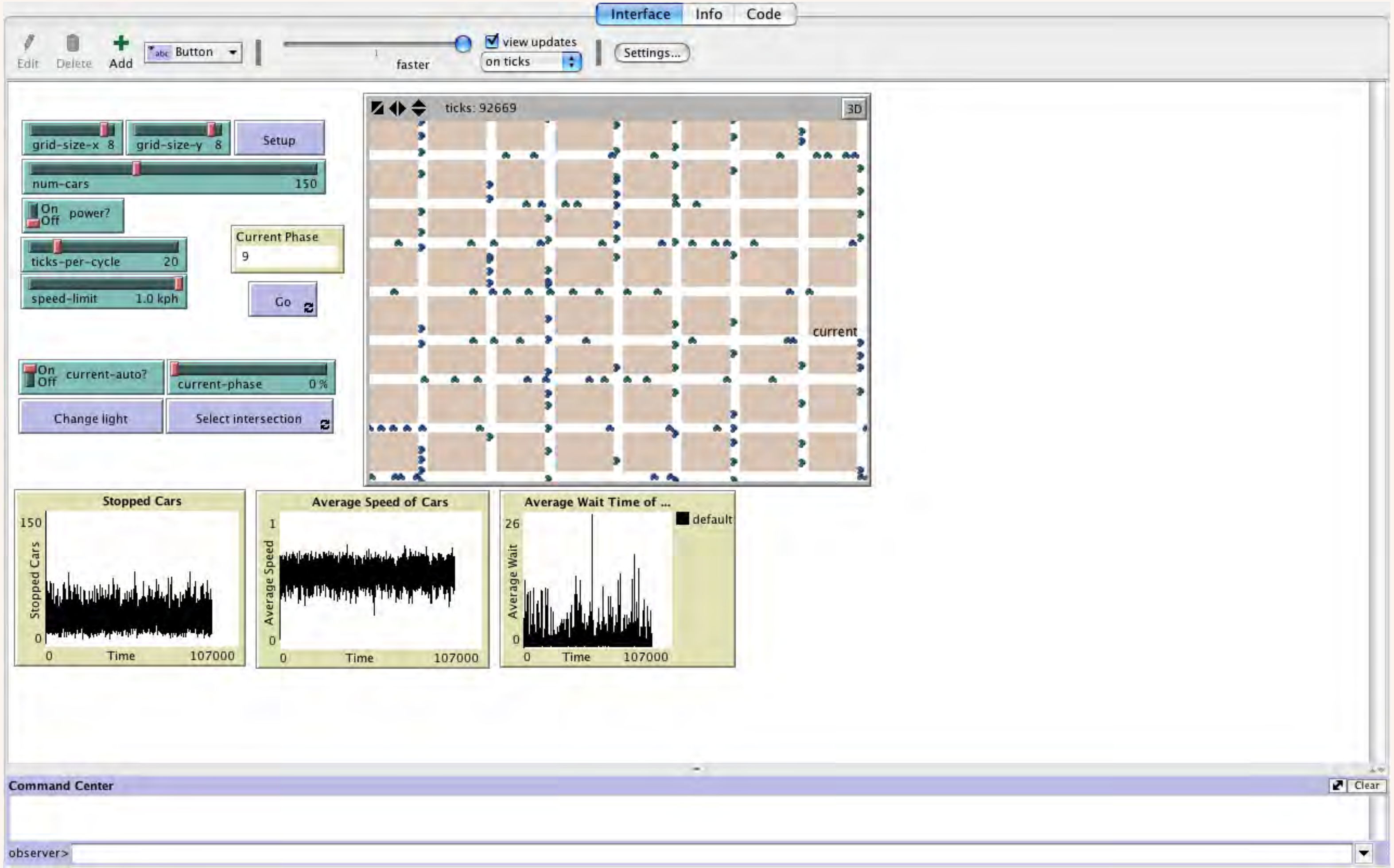
ROUTE EXECUTION PROCESS



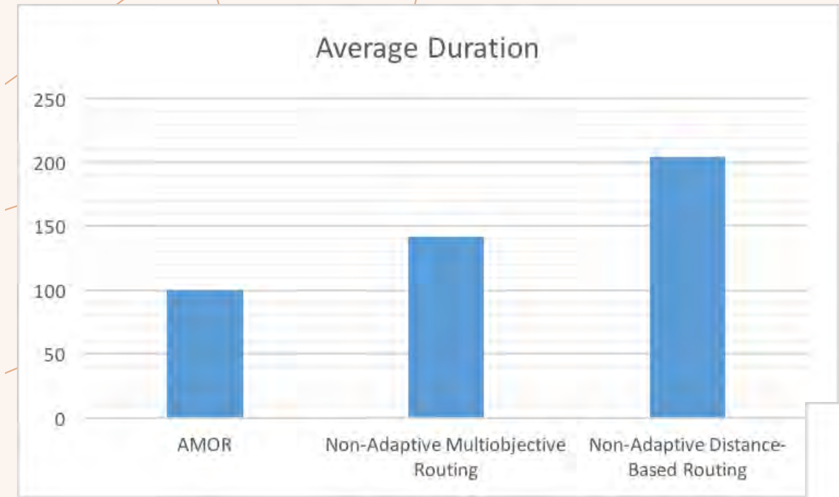
CONCEPTUAL DIAGRAM

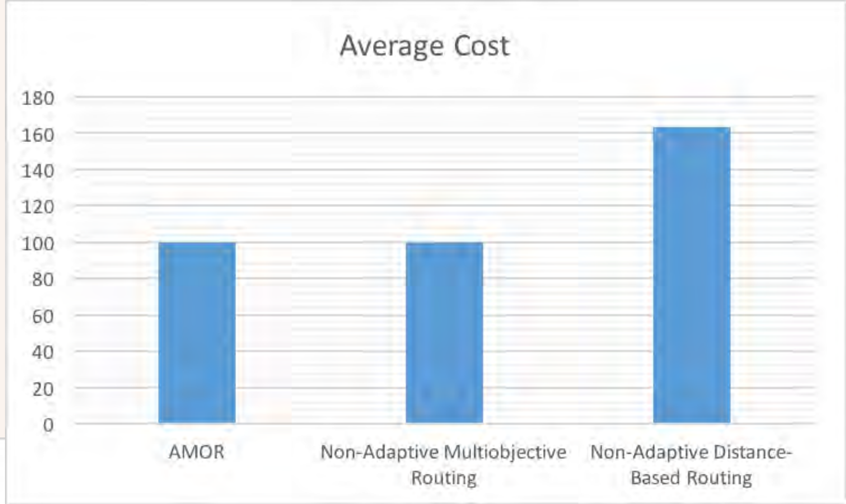
Conceptual architecture diagram Smart traffic management

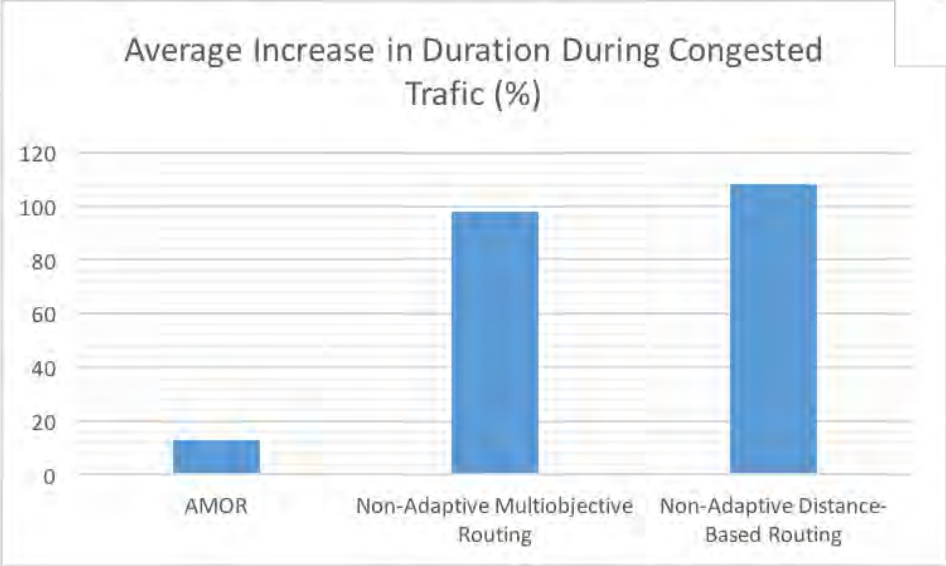
EXPERIMENTAL EVALUATION USING NETLOGO



RESULTS VS. OTHER APPROACHES





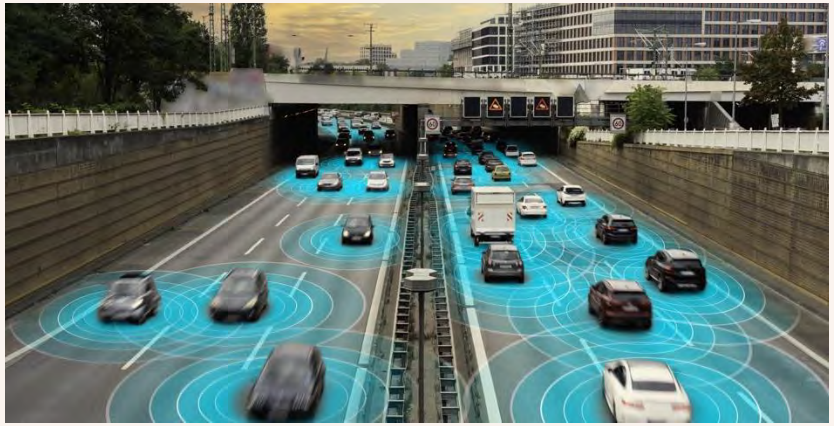


REQUIRED INFRASTRUCTURE

V2X-ENABLED INFRASTRUCTURE

- Smart traffic lights
- Adaptive road signs
- Roadside Units (RSUs)

VEHICLE-SIDE REQUIREMENTS



- V2X-capable vehicles (OBUs)
- In-app agent for standard vehicles

CLOUD + EDGE LAYER

- Local road terminals for fast computation
- City traffic management centre

ASSUMPTIONS

The map of the environment is known

Road segments may have tolls / charges

Historical traffic data are available

Vehicles know their global position

BENEFITS OF AI-DRIVEN TRAFFIC MANAGEMENT

REDUCTION IN TRAFFIC CONGESTION

Traffic Flow Optimization

AI-driven systems enhance traffic flow by analyzing real-time data to optimize signal timings and reduce delays.

Reducing Bottlenecks

Identifying and alleviating bottlenecks in traffic patterns leads to smoother driving experiences and less congestion.

Shorter Travel Times

Decreased congestion translates to shorter travel times for commuters, enhancing overall transportation efficiency.

IMPROVEMENTS IN ROAD SAFETY AND TRAFFIC PRIORITIZATION

Real-time rerouting around road closures

Smart traffic systems play a crucial role in enhancing road safety by optimizing traffic flow and reducing accidents.

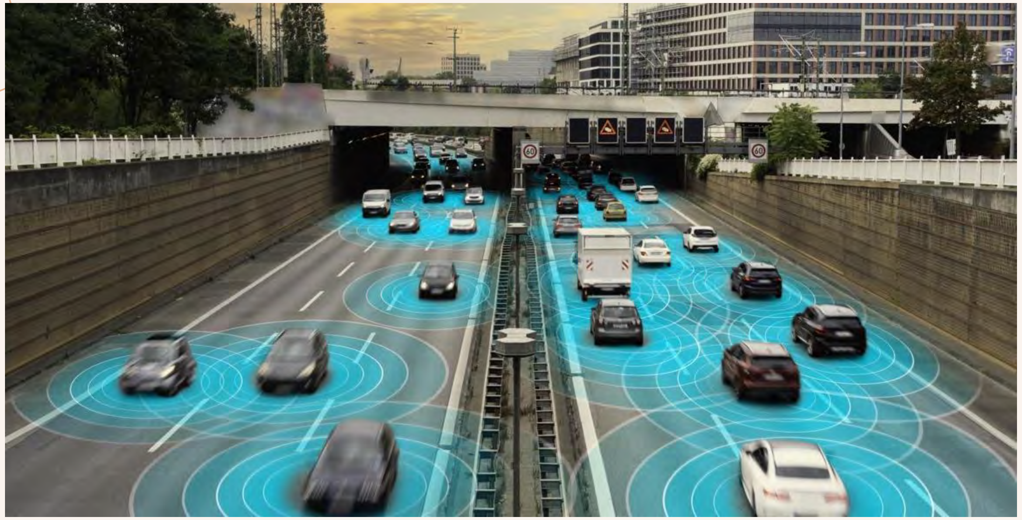
Priority-based Traffic Management

Dynamic prioritization of public transport and emergency services .

Emergency Response Improvement

Ambulances negotiating green wave access

ENVIRONMENTAL BENEFITS AND REDUCED EMISSIONS



Smoother Traffic Flow

Leading to reduced congestion and efficient vehicle movement.

Lower Emissions

By minimizing stop-and-go traffic

Improved Air Quality

Enhanced traffic management contributes to better air quality