

PLATOONING TRAJECTORY AND SIGNAL PHASING OPTIMIZATION FOR CONNECTED AUTOMATED VEHICLES IN COORDINATED ARTERIALS

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Motivation

- In the U.S current signal control strategies account for 295 million vehicle-hours of delay on major roadways alone
- Simulation results suggest that it is possible to reduce delays by exploiting CAVs capabilities
- Several studies have developed signal control algorithms using CAVs at the intersection level, but there are few such studies for arterials

Objective

To develop a heuristic framework to jointly optimize (I) Connected Automated Vehicles (CAVs) trajectories, and (II) Signal Phasing and Timing (SPaT) in coordinated arterials.

I. Trajectory Optimization Methodology

A heuristic approach was developed to adjust CAVs trajectories using the kinematics equations (variable acceleration case) according to vehicles' location (Leader/Follower).

$$\begin{aligned} x(t)_{l,n} &= x(t_0) + \int_{t_0}^t v(t) dt \\ v(t)_{l,n} &= v(t_0) + \int_{t_0}^t \alpha(t) dt \\ \alpha(t)_{l,n} &= y - zt \end{aligned}$$

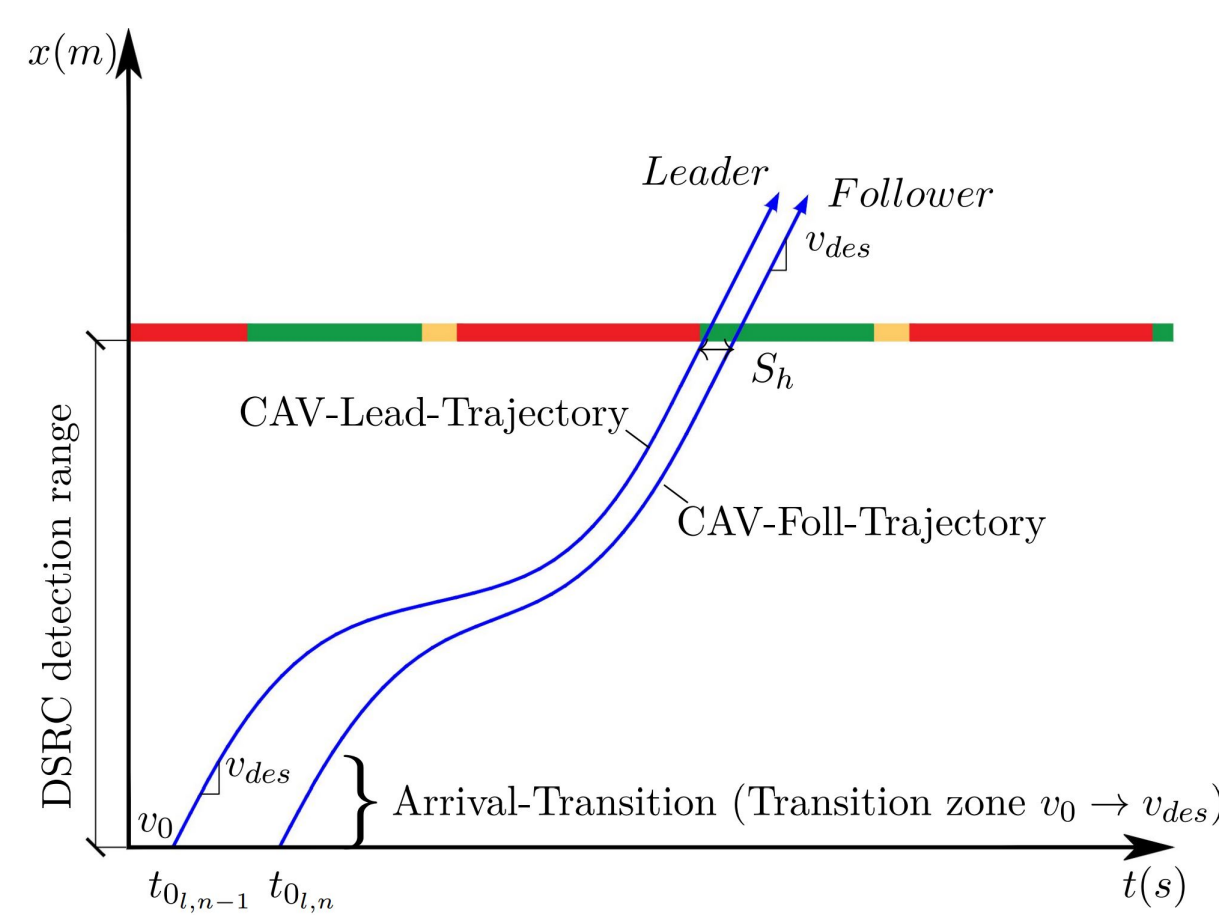


Fig. 1: Concept of trajectory optimization algorithms.

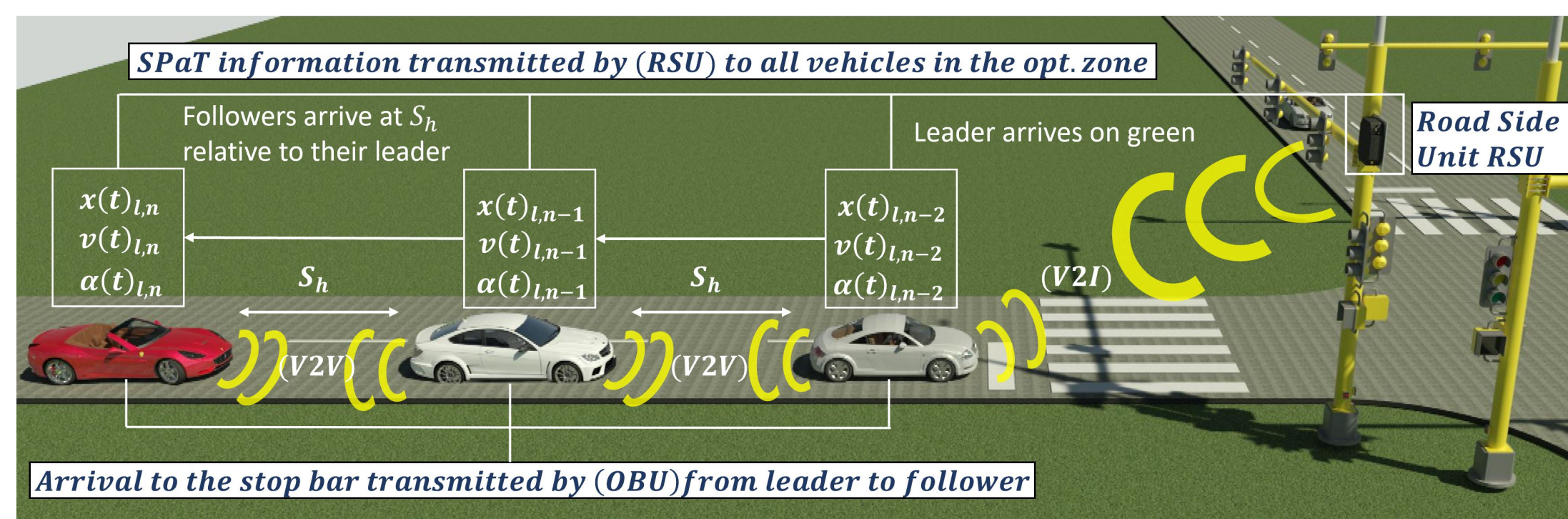


Fig. 2: Conceptual physical framework.



I. Simulation Experiments and Results

Simulation results showed that the trajectory optimization framework successfully form platoons at the saturation headway (S_h) without collision. The results showed that travel time and delay are reduced by (8-22%) and (11-23%), respectively.

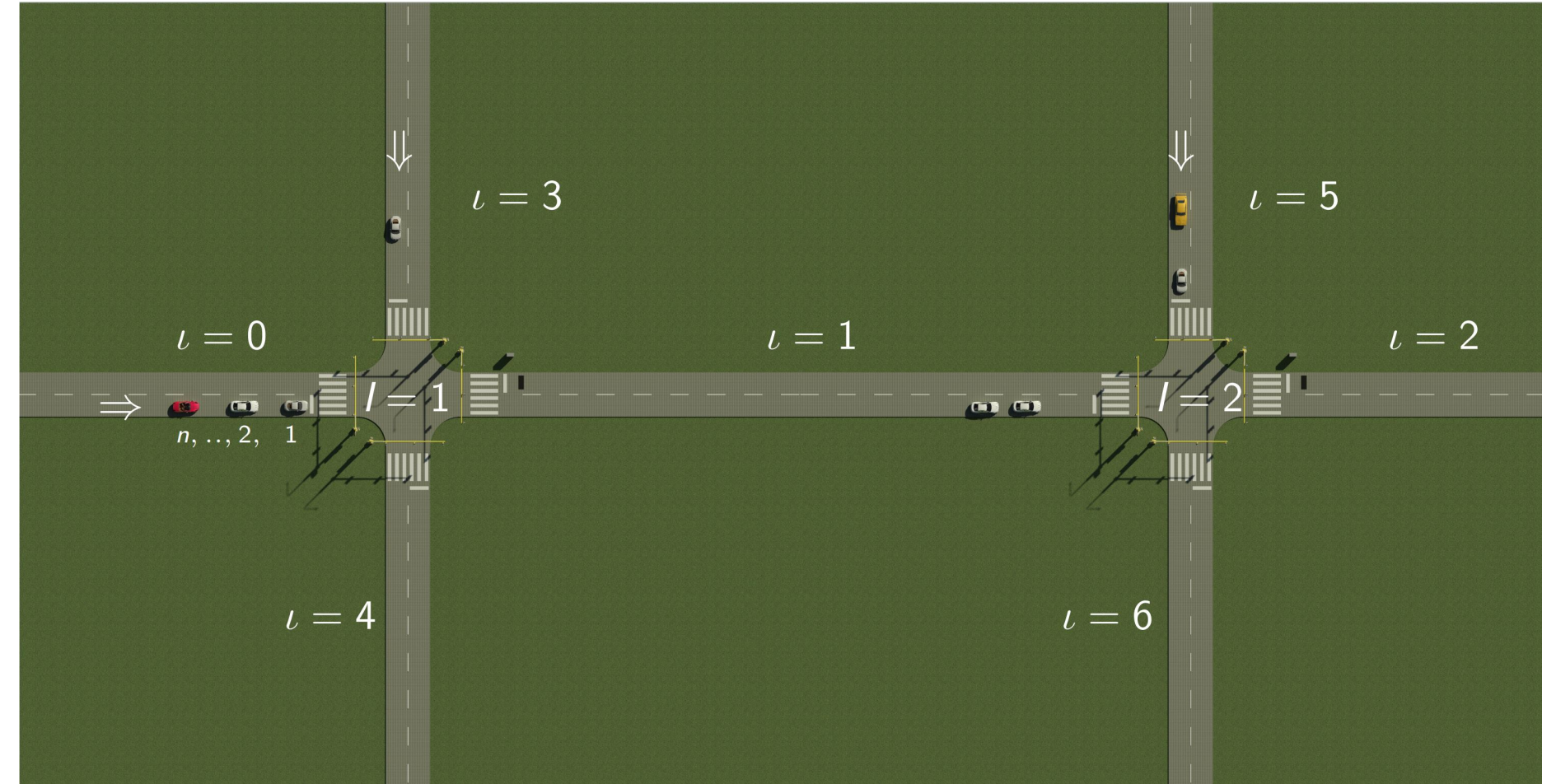


Fig. 3: Study arterial for simulation experiments.

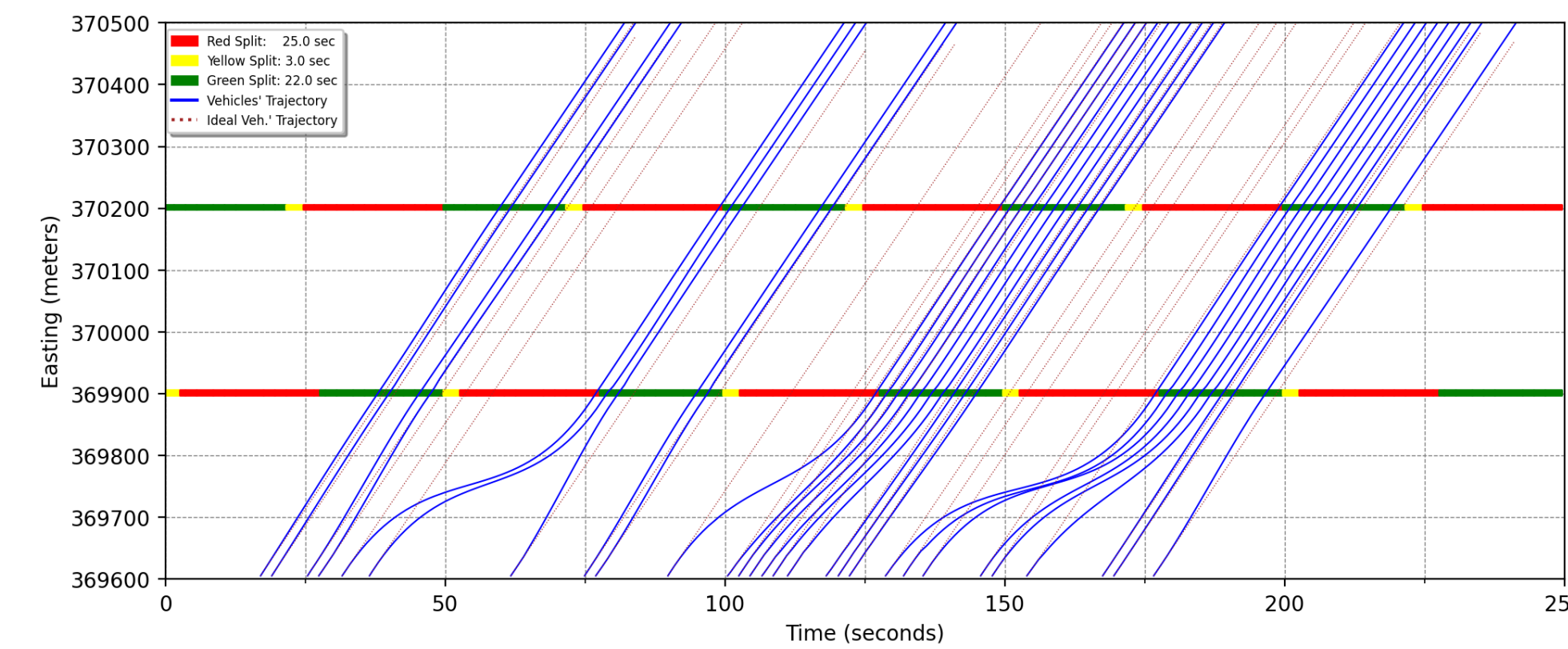


Fig. 4: Time-Space Diagram.

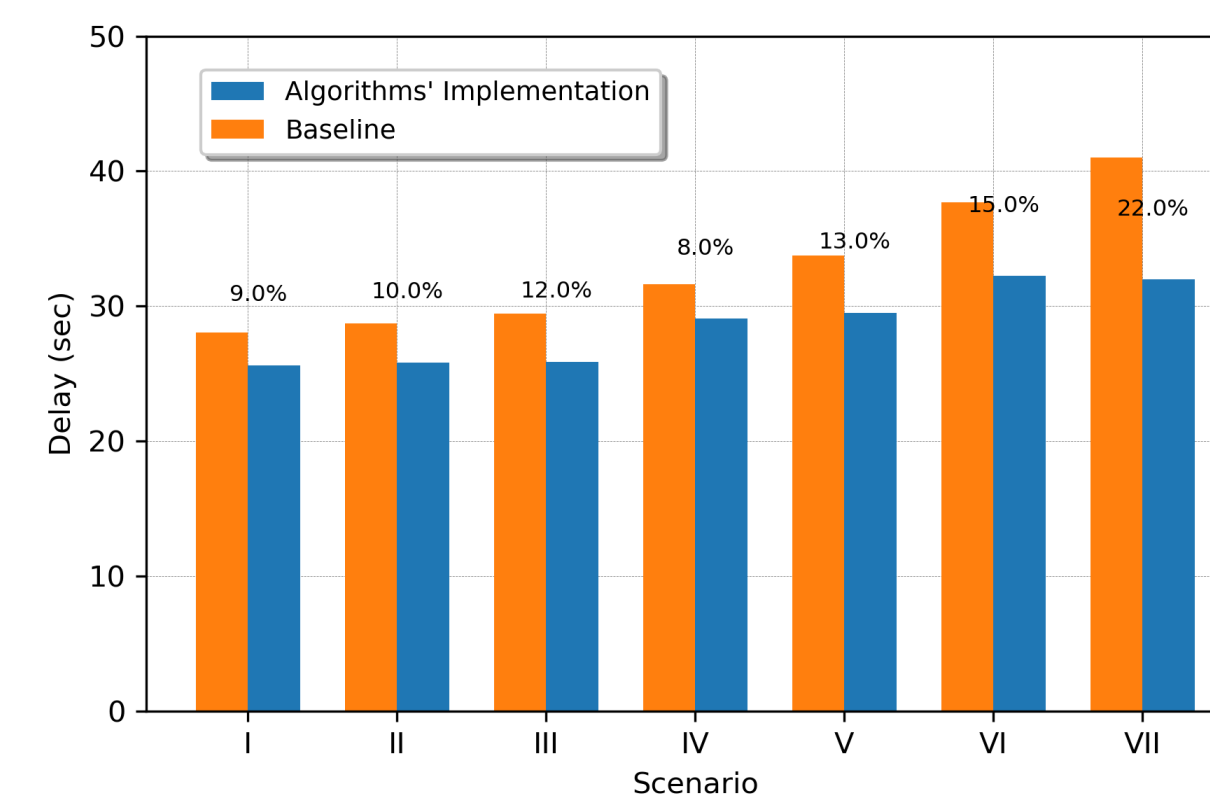


Fig. 5: Average Network Travel Time Improvements.

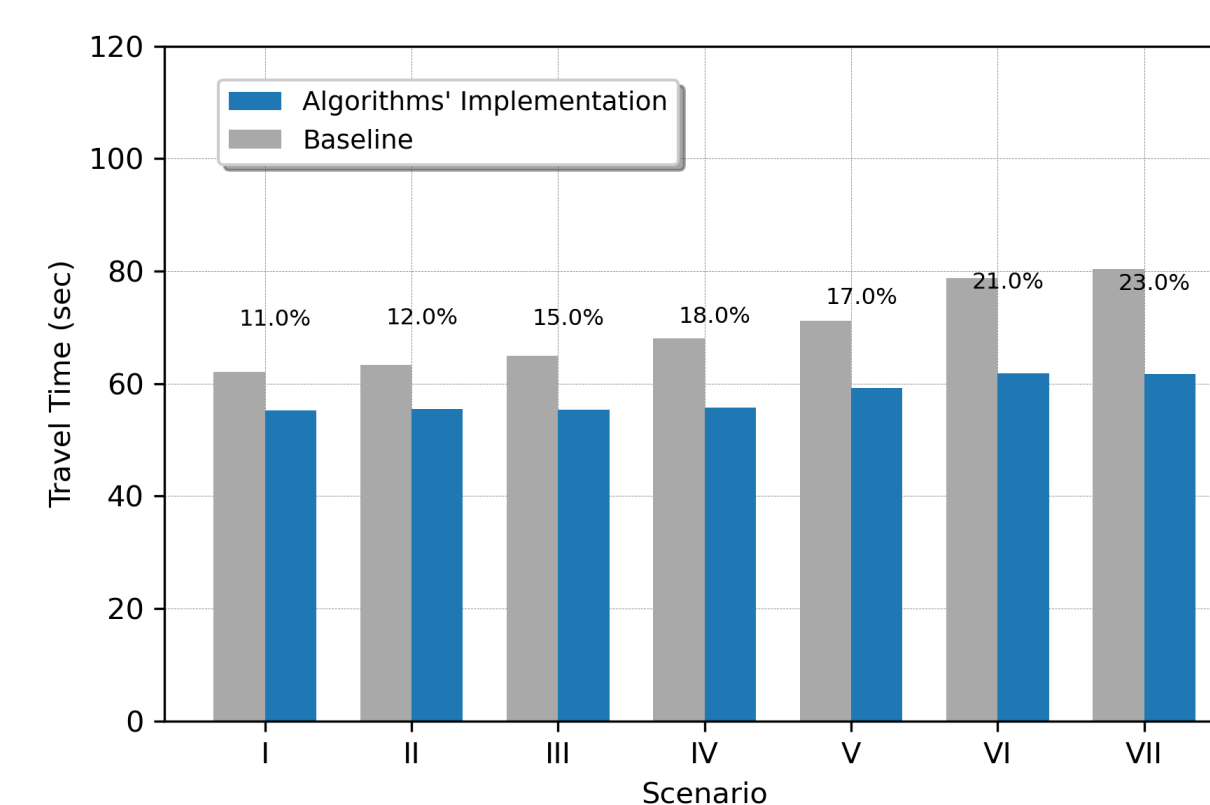


Fig. 6: Average Network Delay Improvements.

II. SPaT Optimization Methodology

A search-based algorithm is designed to optimize the SPaT. A novel Performance Index (PI) is set as the objective function. The PI represents how vehicles' trajectories deviates from their ideal trajectory.

$$\begin{aligned} \max \quad & PI = \frac{1}{V} \sum_{l \in L} \sum_{n \in V_l} \left(\frac{\tau}{\psi} \right)_{n,l} \\ \text{s.t.} \quad & V_l \leq K; \forall l \in L \\ & \tau_{n,l}, \psi_{n,l} \geq 0 \\ & V \in \mathbb{Z}^+ \end{aligned}$$

where:

- L : Set of incoming lanes
- V : Set of all vehicles in $V_l; \forall l \in L$
- τ : Ideal time to the stop bar
- ψ : Actual time to the stop bar
- K : Maximum number of vehicles that can be served at the S_h during the green interval

II. Preliminary Results

Preliminary simulation experiments showed that by adjusting the SPaT according to the PI can reduce travel time and delay by (2-8%) compared to (I).

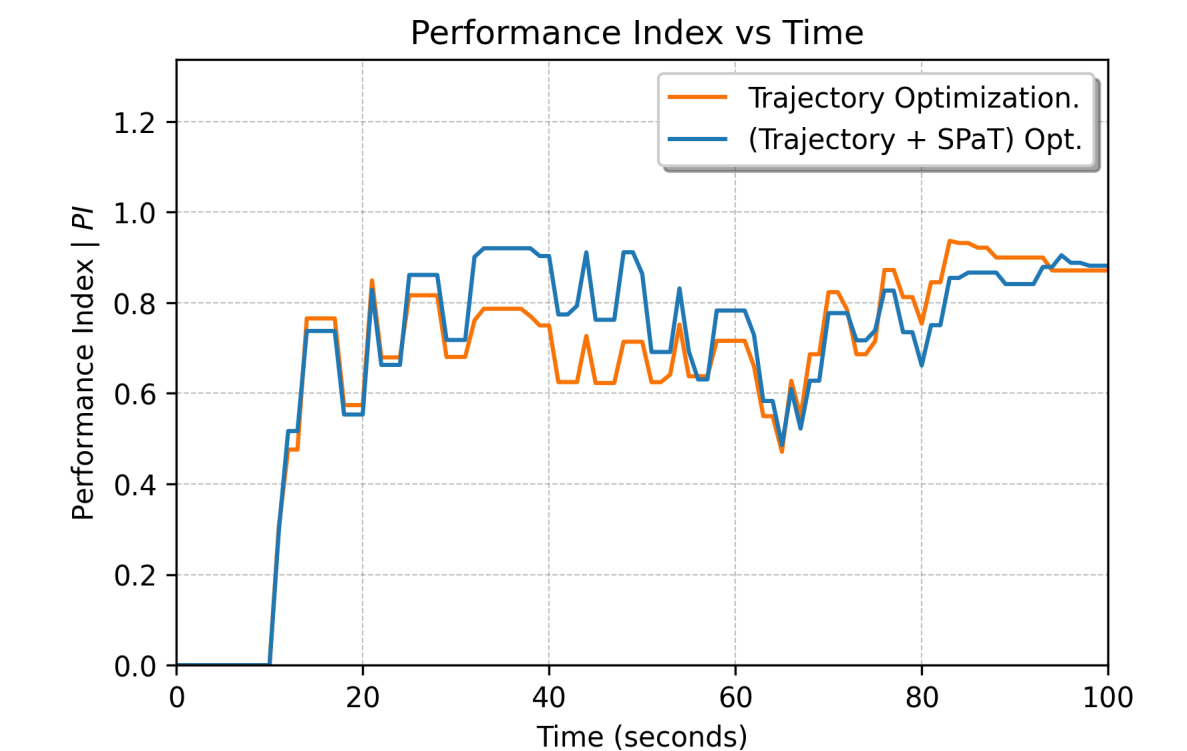


Fig. 7: Comparison of PI variation over time.

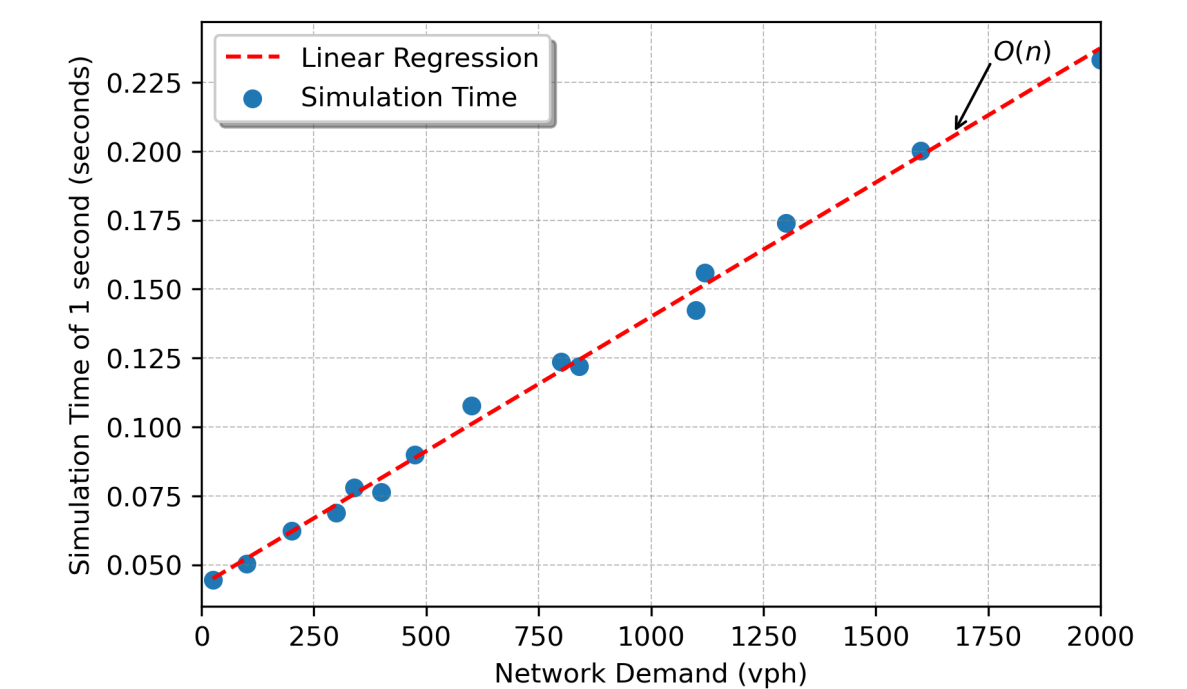


Fig. 8: Empirical time complexity.

Remarks

The time complexity of the algorithms' is quadratic $O(n^2)$. This framework can be extended to Connected-Vehicles (CVs). It is expected that this joint optimization framework will outperformed the previous approach.