Cloud-based Collision-Aware Energy-Minimization Vehicle Velocity Optimization

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Outline

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- System model
- System design
- Performance Evaluation
- Conclusions

Background

Decreasing vehicle energy consumption has been considered as an extremely important issue for transportation system.

Optimizing vehicle velocity is one of the most effective methods to reduce vehicles' energy consumption.

Background

Existing work (vehicular cloud): consider each vehicle as an independent object and neglect the influence between consecutive vehicles in single lanes.

Problem: Although a vehicle may pass its preceding vehicle through a neighboring lance, the influence between the consecutive vehicles in a single lane cannot be neglected, since most vehicles need to travel through single lanes in reality.

Background

Challenge:

1) Non-convex constraints.
2) Difficult to process all vehicles' information together.

Contribution:

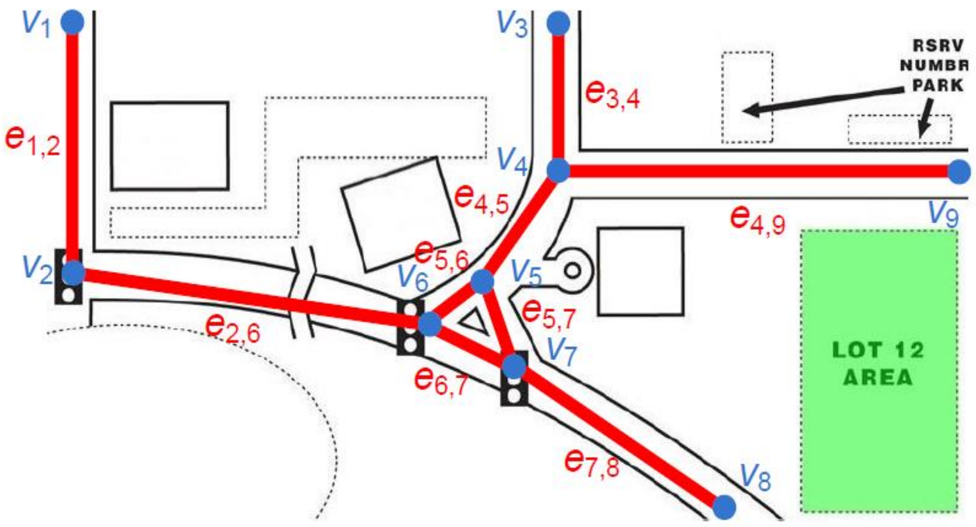
1) A time efficient solution to derive the optimal velocity.
2) Performance evaluation via real trace simulation.

System Model

Vehicle traffic model:

K vehicles are running on the roads; each vehicle's travelling route and time constraint are given.

The road can modeled as a map *G* = (*P*, *E*), as shown on the right.



System Model

Vehicle energy consumption model: (comprehensive model mission model)

$$J(v_{k,t}, a_{k,t}) = \frac{1}{44}\left(\frac{A_3 v_{k,t}^3 + A_2 v_{k,t}^2 + A_1 v_{k,t} + M a_{k,t}}{0.4\eta_{\mathrm{tf}}} + V\right)$$

System Model

Problem Formulation

Constraint

1) Speed limit constraint $v_{k_i,k_{i+1}}^{\min} \leq v_{k,t} \leq v_{k_i,k_{i+1}}^{\max}.$
2) Driver's comfort constraint $a_{\min} \leq a_{k,t} \leq a_{\max},$
3) Stop sign constraint $v_{k,t} = 0, \text{ if } v_{k,t-1} \neq 0 \text{ and } d_{k,t} \in \mathscr{D}_{\text{stop}}$
4) Traffic light constraint $v_{k,t} = 0, \text{ when } t \in \mathscr{T}_{k,l}^{\text{red}},$
5) Vehicle influence constraint $d_{i,t} - d_{i,t_i} < d_{j,t} - d_{j,t_j}, \forall t$

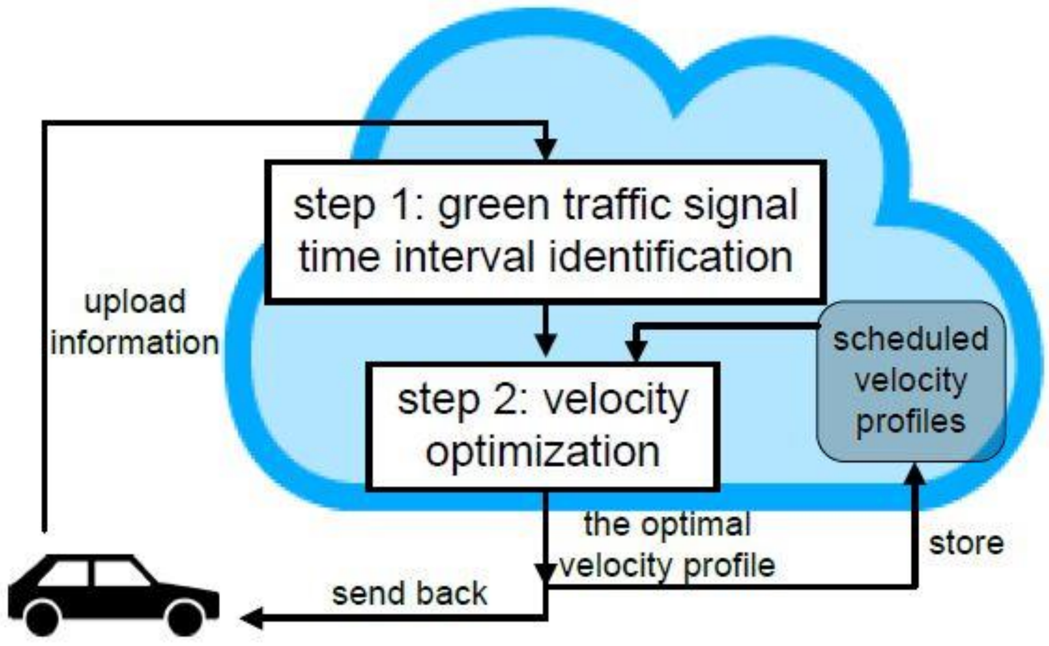
Objective function

Minimize the overall energy consumption: $\min \sum_{k=1}^{K} \sum_{t=t_{k_0}}^{t_{k_0}+T_k} J(v_{k,t}, a_{k,t})$

System Design

Step 1: Green traffic signal time interval identification.

Step 2: Velocity optimization.



Architecture of our system

System Design

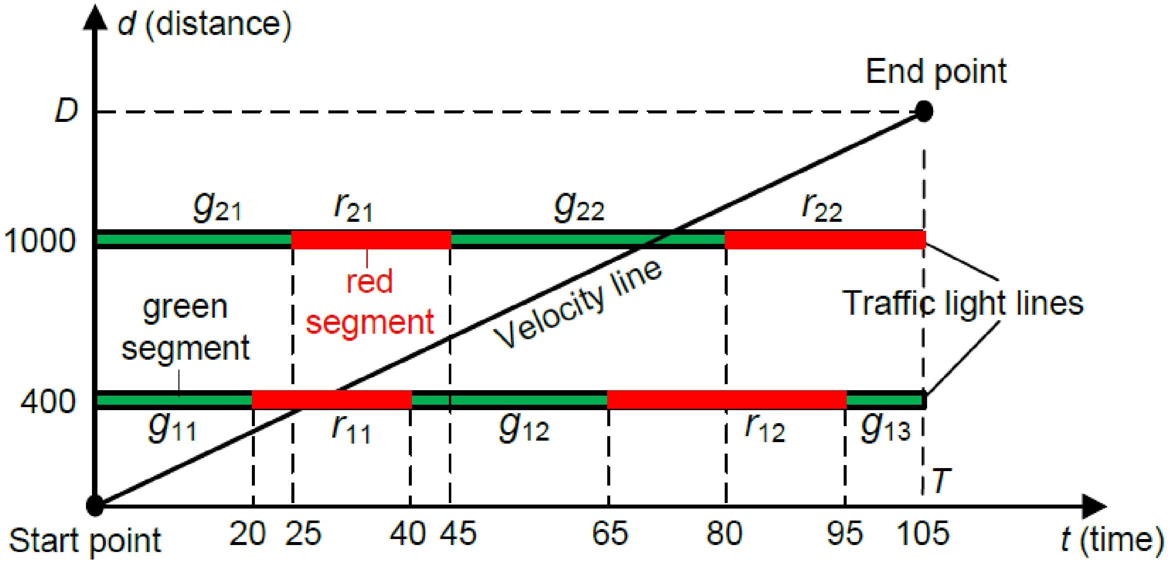
Constant velocity principle

Given the time limit *T* and the travel distance *D*, the vehicle's total energy consumption is minimized when the vehicle's velocity is constant at each time point.

Proof: Power means inequality

System Design

Green traffic signal time interval identification



System Design

Velocity optimization

The vehicle’s velocity is scheduled sequentially. Each schedule should avoid the collision with the previous scheduled vehicle.

The newly formulated problem has only linear constraints.

Performance Evaluation

Settings:

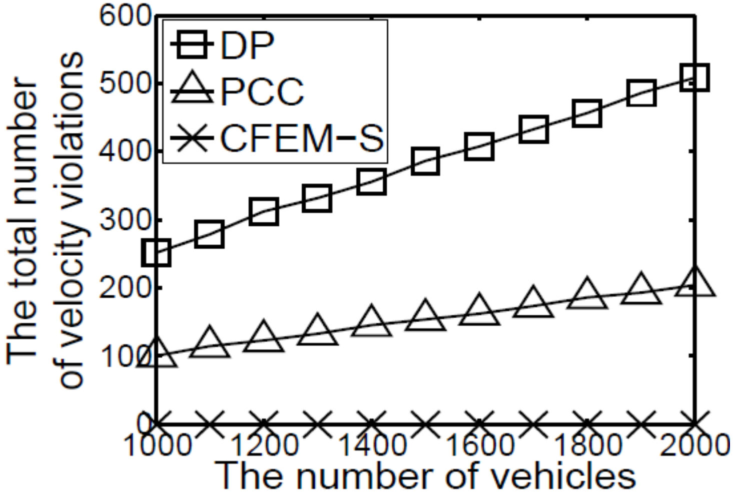
1. Vehicle mobility trace from the Cologne urban area, covering a region of 400 square kilometers with 404 traffic lights. The trace records the locations of more than 700,000 individual vehicle trips for a time period of 24 hours.
2. We randomly picked up a number of vehicles (the number is changed from 1000 to 2000).

Methods for comparison:

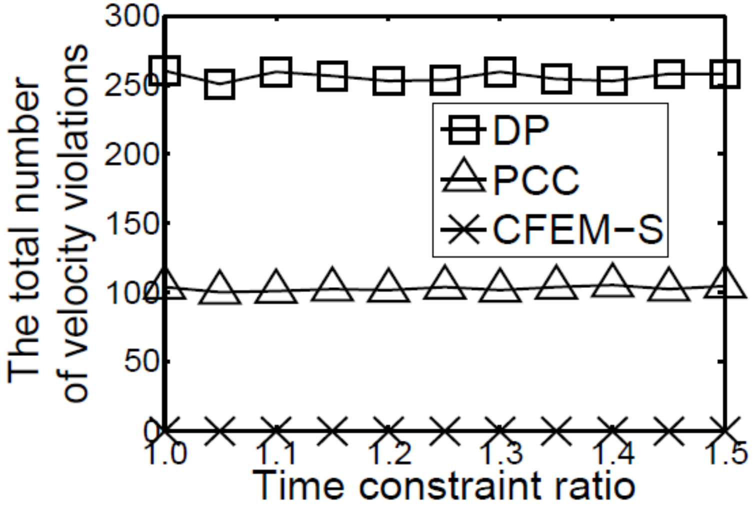
1. PCC (predictive cruise control)
2. DP (dynamic programming)

Performance Evaluation

Simulation: the total number of velocity violations



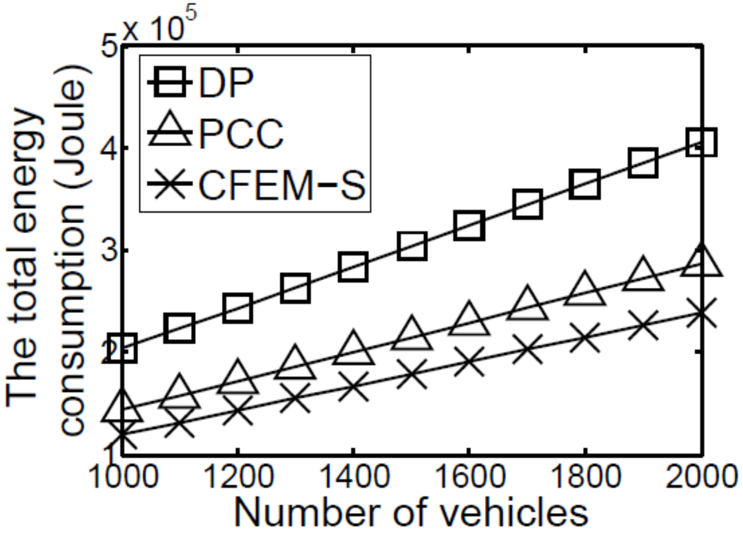
(a) Different # of vehicles (time constraint ratio = 1.0)



(b) Different time constraint ratio (# of vehicles = 1000)

Performance Evaluation

The total energy consumption



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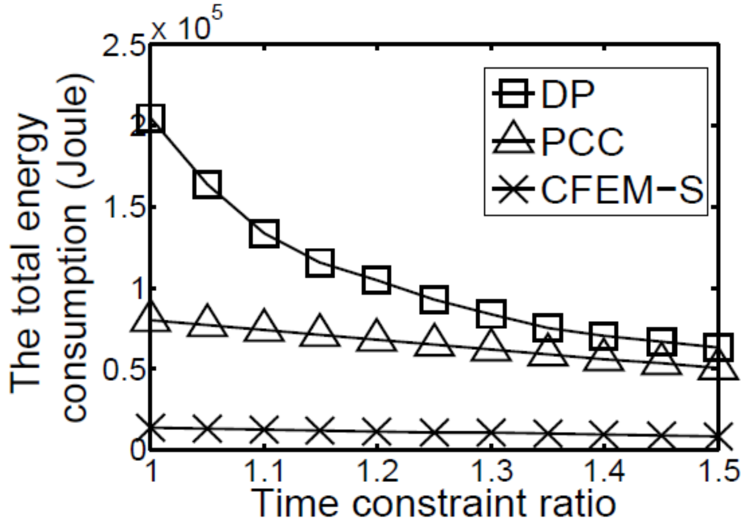
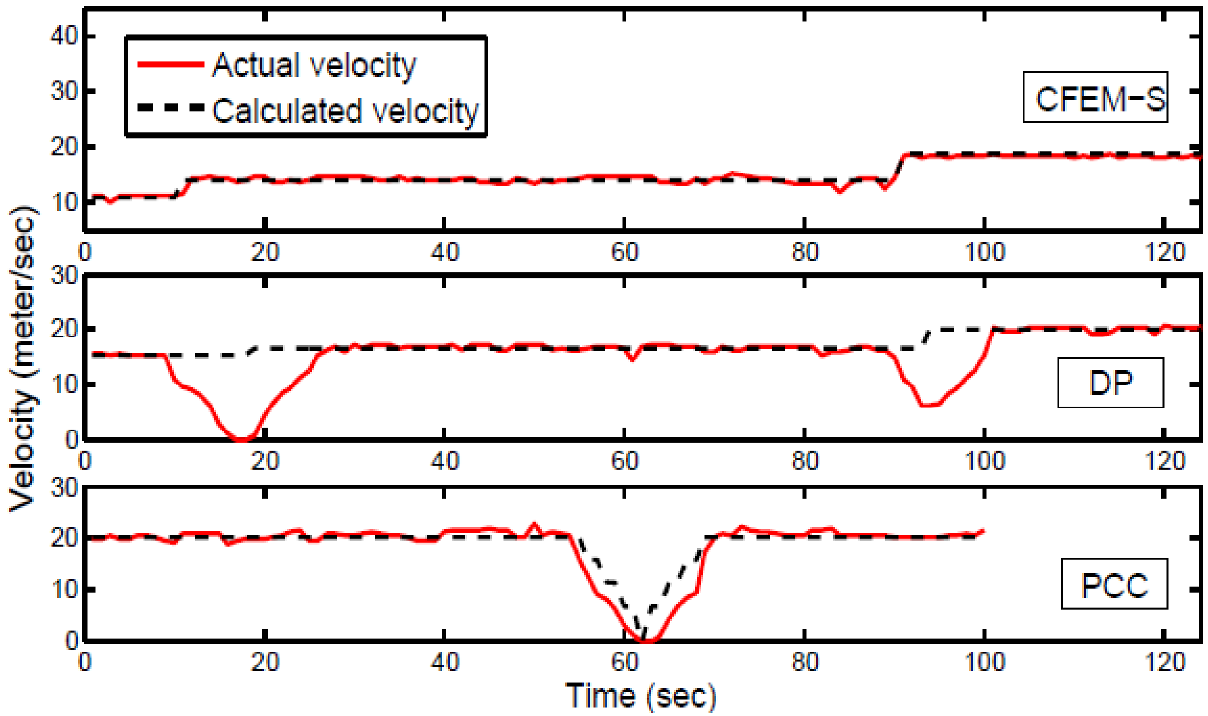


(b) Different time constraint ratio (# of vehicles = 1000)

Performance Evaluation

How vehicle follow the suggested velocity under the three methods



Conclusions

1) We formulated a new velocity optimization problem to consider the possible interaction between vehicles.
2) We proposed a time efficient solution to derive the optimal velocity.
3) We evaluated the performance of our solution via real trace simulation.

Future work:

1) Interaction among vehicles in multiple lanes.
2) How to avoid the collision with human-determined vehicles.
3) How to optimize other metrics, like reducing vehicles' traveling time.

Thank you!

If you have any questions, please contact

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