UNIVERSITY OF TWENTE.

Green-wave analysis in a tandem of traffic-light intersections

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Overview

- Network of intersections
- Stochastic model
- Numerical results

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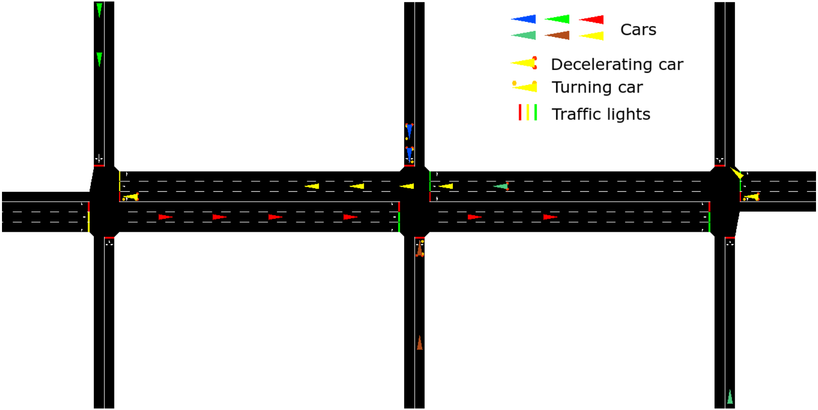
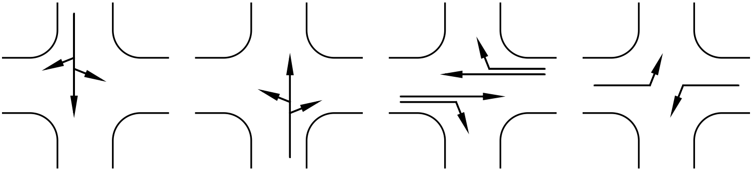
Network of intersections



Network of intersections: phases



Phase 1 *Phase* 2 *Phase* 3 *Phase* 4

- Fixed length of each phase.

Network of intersections: fixed control

- Each lane has fixed green and red times.

  no real-time data
- Fixed common cycle length, c, in the network.

  coordination between intersections
- Control parameters: green times and offsets.

  offset is time between coordinated phases
  of two intersections

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Stochastic model: problems

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  discrete-time model

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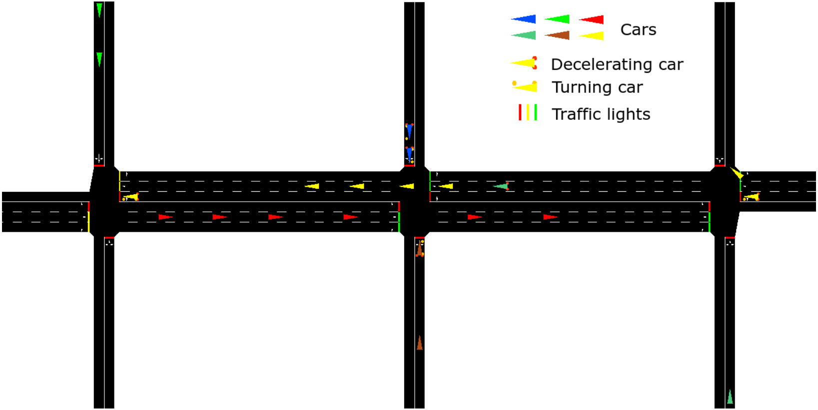
- High dimension of the system.

  network decomposition into separate lanes

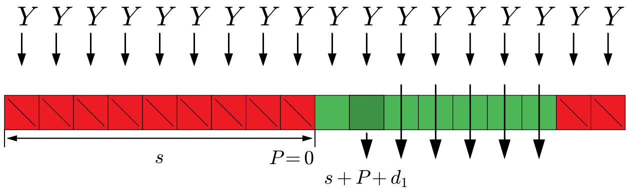
- Dependency between lanes.

  arrival process

Stochastic model: network



Stochastic model: external lane



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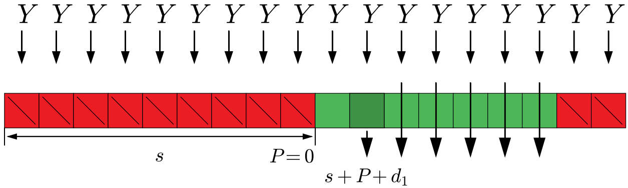

- Bernoulli arrivals: i.i.d. Y.

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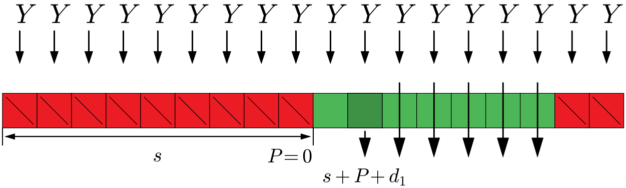

- Bernoulli arrivals: i.i.d. Y.
- Delayed departure at second $s + P + d_k$, where
  s — beginning of the green time, P — distraction variable,
  d_k — deterministic second of the k^{th} delayed vehicle.

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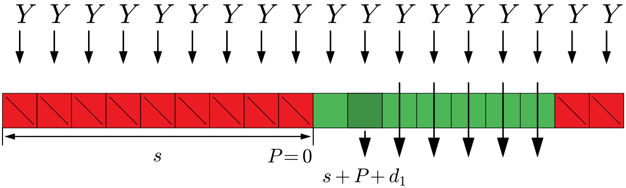

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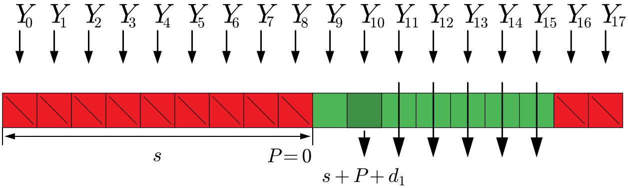
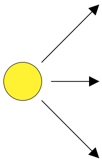
- Delayed departure at second $s + P + d_k$, where
  s — beginning of the green time, P — distraction variable,
  d_k — deterministic second of the k^{th} delayed vehicle.
- If the queue becomes empty, all the arrivals proceed without stopping.

Stochastic model: internal lane



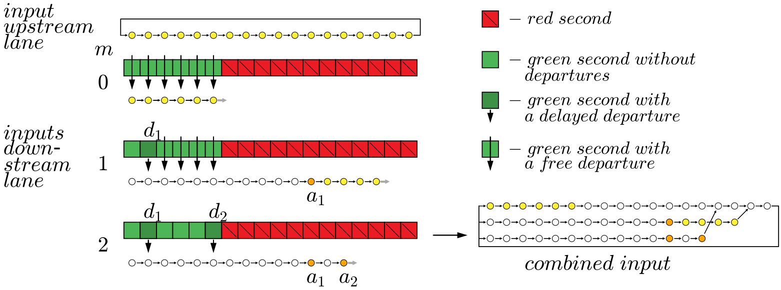
- Correlated arrivals.
- Acceleration of the delayed departures.

Markovian arrival process



- Underlying Markov chain L_i, $i = 0, \ldots, c-1$.
- States represent information that determines arrivals, e.g., the number of delayed departures at the upstream lane.
- $\mathbb{P}(Y_i = 1 | L_i = l, Y_0, \ldots, Y_{i-1}) = \lambda_i^l$.

Markovian arrival process



Independence assumption

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Under this assumption, we prove that the pgf of the queue length at a lane at the beginning of the cycle has form:

$$X(z) = \frac{\sum_{j=0}^{n-1} x_j f_j(z)}{z^n - A(z)C(z)},$$

where n is the maximum capacity, $x_j = \mathbb{P}(X_0 = j)$, $A(z)$ — the pgf of arrivals, $C(z)$ — the pgf of the lost capacity due to randomness of P, $f_j(z)$ — polynomials.

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Green-wave efficiency

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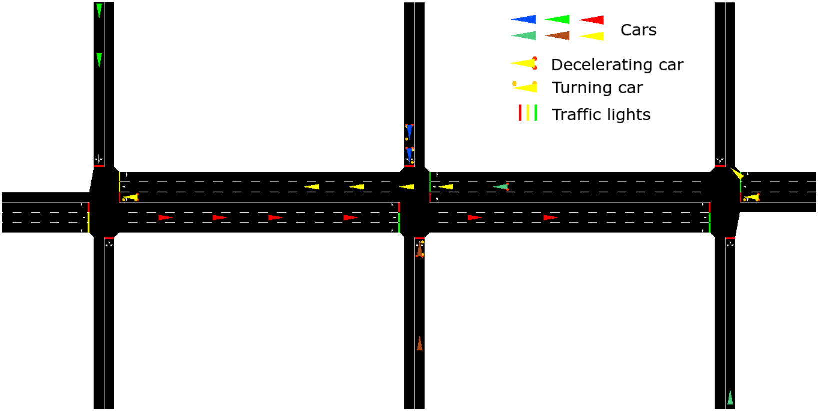
Definition The *green-wave efficiency* is the expected number of intersections passed without stopping for an arbitrary vehicle.

- In an ideal green wave, the green-wave efficiency is equal to the expected number of intersections for a vehicle.
- In the worst case scenario, all of the vehicles need to stop, and our measure is equal to 0.

Optimisation: network of intersections



Optimisation: parameters

We consider a tandem of 3 intersections (100 meters apart):

- the arrival rate from west is λ,
- the arrival rate from east is 0.5λ,
- the arrival rate from north and south is 0.2λ,
- 16% of the major traffic turns south or north,
- 40% (20%) of the minor traffic turns east (west).

Optimisation: objectives and constraints

Optimisation with multiple objectives:

- maximising the green-wave efficiency,
- minimising the average delay

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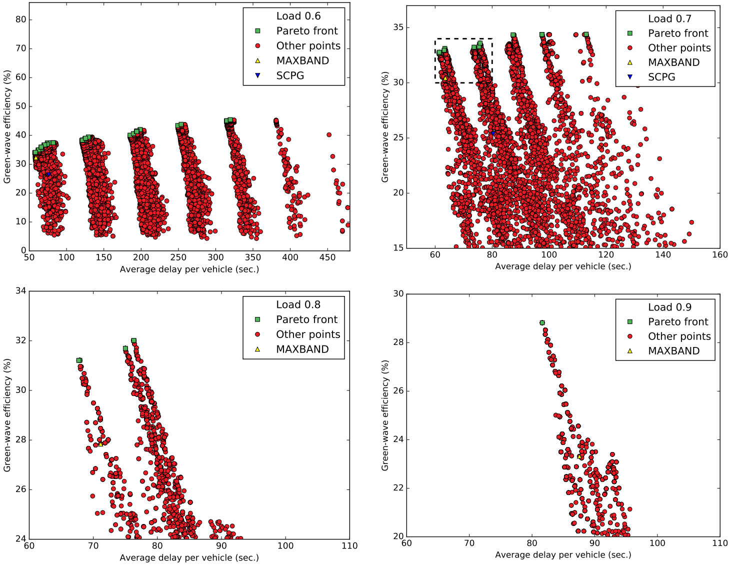
for

- fixed cycle length of 60 seconds,
- given phase schedule.

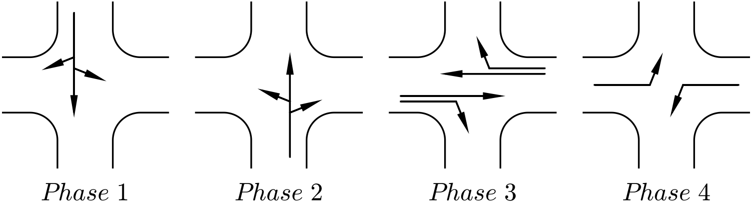
Optimisation: approaches

- Genetic algorithm coupled with our model,
  multiple objectives
- SUMO cycle program generator (SCPG),
  Webster (proportional) green time allocation
- MAXBAND.
  bandwidth maximisation

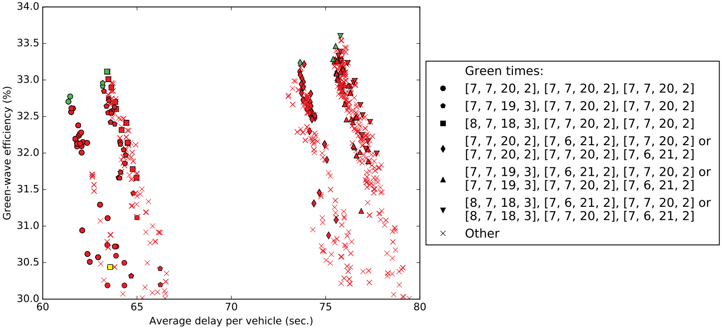
Optimisation results: Pareto optimality



Optimisation: phases



Optimisation results: Pareto optimality load 0.7



Conclusions

- It is important to take the real behaviour of traffic into account.
- Optimisation for the best green wave may be disadvantageous for the average delay.
- The average delay per vehicle is very sensitive to the changes in the green times.