Traffic-actuated Signal Control: Simulation of the User Benefits in a Big Event Real-World Scenario

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ABSTRACT

Making traffic signals adaptive may play a key role in intelligent transport systems, since it will enable an already existing infrastructure to react to the variabilities of the system. In this paper, a micro-simulation model for traffic-actuated signal control is used that is able to capture network, time, and second order effects of policy changes. In a real world scenario, a traffic-actuated signal control strategy from industry is tested for its use at large events such as football games. Without any special adjustments, the traffic-actuated algorithm performs better than a fixed time control scheme.
Keywords: *traffic-actuated signal control, multi-agent transport simulation*

INTRODUCTION

Fixed-time signal control is frequently used in practice, and subject to current research. For example, under the assumption of a stable demand over specific time intervals like the morning peak, fixed time control can be optimized [1]. To capture the variability of traffic load over time, several such optimizations can be used, each for a predefined time period.

However, traffic systems have some inherent stochastics that may have an extrinsic source, e.g. weather, or that are intrinsic, e.g. from construction works or accidents. Intelligent transport systems (ITS) play a key role to deal with those uncertainties, as most of the technologies developed in an ITS context are able to react to unexpected state changes of the transport system. One of the key elements of ITS applications may be signal systems that react to the current traffic state, and thus are able to absorb some randomness of the transport system. It is not clear, however, if traffic actuated signal control improves the system as a whole. It has already been shown that traffic actuated signal systems need to obey some mathematical constraints because otherwise they may become unstable at the network level and thus perform much worse than fixed time control in some situations [2].

Even if traffic-actuated signal control improves traffic conditions at a crossing, it might not result in benefits for the system as a whole. Induced traffic as a result from an improved signal control at single nodes is reported by [3]. Ref. [4] argues that second order or network effects should be taken into account when effects of signal control strategies are tested. Network effects include drivers' reactions not only in terms of route choice but also in terms of scheduling. Most of the known existing microscopic traffic simulations focus on detailed driver models that extend car following models in a certain way. Thus driving behaviour is simulated in detail, yet in most cases this is done for one trip. Doing so, one loses information to capture network effects and time shifts that have already been studied for other policies[5]. This abstract uses a signal control simulation technique to capture such effects in large scale networks.

The simulation technique is used in order to evaluate the performance of the traffic-actuated signal control strategy SYLVIA. There are many control strategies used in practice, e.g. SCOOT, SCATS, MOTION, or BALANCE. SYLVIA has the advantage that it is easy to understand, it needs little calibration, and it can be set up starting from fixed-time signal control. The last aspect is important since this study is done in the context of fixed-time signal optimization research [1].

This extended abstract introduces briefly the simulation model, before SYLVIA, the traffic-actuated signal control algorithm, is presented. The scenario used for simulation is based on real world data and is introduced afterwards. Then results of simulation runs are presented.

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SIMULATION APPROACH

The simulation approach used in this paper is based on the software tool MATSim[1]. In MATSim, each traveler of the real system is modeled as an individual virtual person. The approach consists of an iterative loop that has the following important steps:

1. **Plans generation**: All virtual persons independently generate daily *plans* that encode, among other things, their desired activities during a typical day as well as the transportation mode. Virtual persons typically have more than one plan ("plan database").

2. **Traffic flow simulation**: All selected plans are simultaneously executed in a simulation of the physical system (often called "network loading"). Within the traffic simulation traffic signals are microscopically modelled, details are presented in [6].

3. **Scoring**: All executed plans are scored by an *utility function* which can be personalized for every individual.

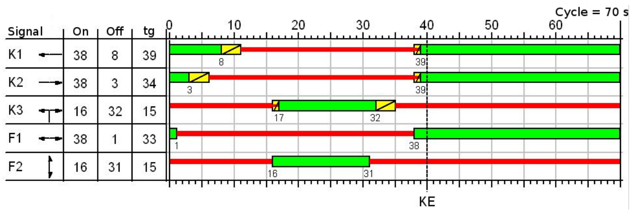
4. **Learning**: At the beginning of every iteration, some virtual persons obtain new plans by modifying copies of existing plans. This is done by several *modules* that correspond to the choice dimensions available, e.g. time choice, route choice, and mode choice. In this paper, only route choice will be used. Virtual persons choose between their plans according to a Random Utility Model (RUM).

The repetition of the iteration cycle coupled with the plan database enables the virtual persons to improve (learn) their plans over many iterations. The iteration cycle continues until the system has reached a relaxed state. At this point, there is no quantitative measure of when the system is "relaxed"; we just allow the cycle to continue until the outcome is stable.

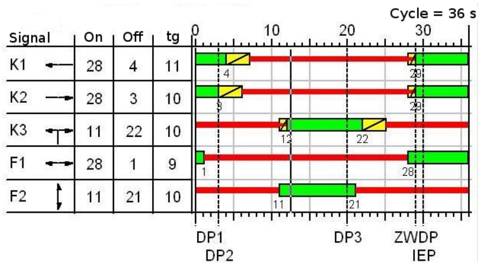
SYLVIA: TRAFFIC ACTUATED SIGNAL CONTROL

In this paper a signal control strategy from industry called SYLVIA[2] is used [7]. Originally developed by Siemens in the nineties , currently Schlothauer & Wauer[3], a German engineering company, is developing and supporting this signal control strategy. SYLVIA is not a closed, unique algorithm for signal control. Rather, it consists of several modules that can be used standalone or in conjunction.

In this work the focus is on one of the main features of SYLVIA, the traffic actuated stage length control. This is based on pretimed fixed-time signal programs. An example signal timing plan with a cycle of 70 seconds, three signals for car traffic (K1 – K3), and two signals for pedestrian traffic (F1, F2) is shown in Fig. 1(a). To use traffic actuated stage length control, first the pretimed signal timing plan is compressed to a *base plan* (Fig. 1(b)). Green of all signal groups is reduced to a minimal time, in this example to about 10 to 12 seconds. The cycle of the base plan is thus reduced to 38 seconds. Then, extension points are specified. An extension point is a point in the base plan where, if desired, the green time can be extended. A traffic engineer manually specifies extension points, minimal and maximal extension times for each signal group, and a condition for extension. The condition if a signal green should be extended is set with respect to the detectors which are available at the crossing. If the timer of the signal controller reaches an extension point in the base plan, the condition set for extension is checked. While the condition is true the green time is extended until a maximum extension time is reached.



(a) Fixed-time signal plan



(b) Base plan needed for traffic actuated stage length control

Fig. 1: Traffic signal plans. Source: Modified from [7].

SCENARIO: COTTBUS, GERMANY

The simulation scenario used in this paper is located in the south of the federal state of Brandenburg, in Germany. It covers the area of the administrative district "Spree-Neiße" that is enclosing the city of Cottbus, plus the City of Cottbus itself.

[1]Multi-Agent Transport Simulation, see www.matsim.org.

[2]"SYstem Leipzig für die Verkehrabhängige Individuelle Steuerung von LichtsignalAnlagen"

[3]see http://www.schlothauer.de/en/index.html, last access 17.01.2011

Network & Population The network is taken from OpenStreetmap[4] data. The network consists of 4417 nodes and 10600 links and is depicted in Fig. 2.

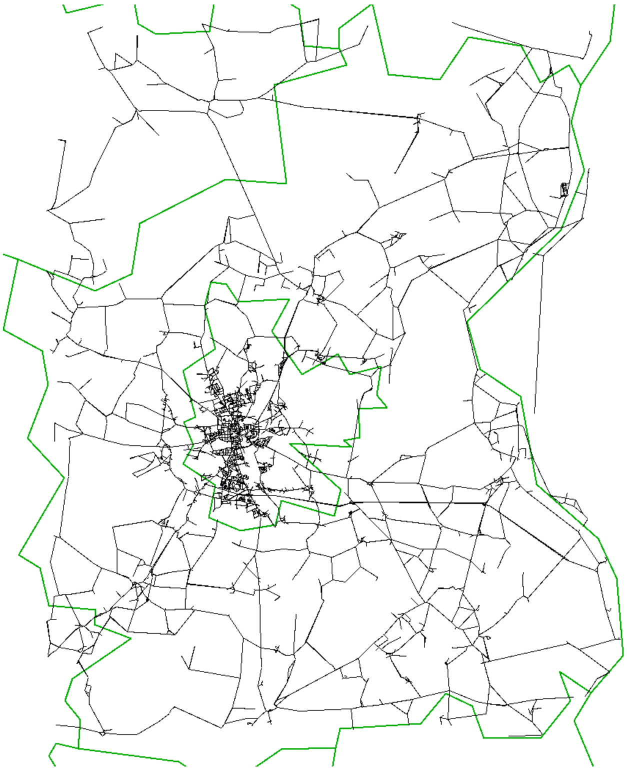


Fig. 2: Road network. The green lines mark the area of the administrative district while black lines represent roads of the traffic network.

In the city of Cottbus live around 100000 inhabitants while approx. 128000 people reside in the administrative district Spree-Neiße. The synthetic population used for simulation is based on data taken from the German employment agency [8]. For simulation a 100 % sample of 33'479 commuters travelling by car is used.

Large Event The football stadium of Cottbus lies in the south-east of the city area and accomodates up to 22528 fans[5]. The local football club "FC Energie Cottbus" currently plays in Germany's second league so that it may happen that some kind of derby takes places on a normal weekday, thus interfering with the regular commuter traffic. In the area of the stadium around 2000 parking lots are available[6]. Thus in addition to the commuters, a synthetic population with up to 2000 persons travelling by car to the stadium is created. It is assumed that 25 % of these fans come from Cottbus, while the other 75 % come from the "Spree-Neiße" area, and that all fans start their trips between 5 and 6 o'clock (p.m.) in the evening.

Traffic Signals Within the city area of Cottbus, fixed-time control schedules for 24 signal systems are available provided by BTU Cottbus. All signal control plans have a cycle of 90 seconds. Green splits are taken from the currently running system, and offsets are optimized by [1]. Note that the demand used for optimization differs from the commuter demand used in this work. That reflects the typical case of optimized fixed-time control: Signals are optimized to a certain demand once but while the demand changes over time the fixed-time control is not readjusted anymore.

The fixed-time data serves as input for the generation of base plans for SYLVIA: Phase ordering and intergreens are taken over. In the SYLVIA base plan, green is set to 5 seconds for all phases, which is the minimal green time in Germany [9]. Extension points for green time extension are placed one second before the end of green in each phase. Maximum green is set to the phase length of the fixed-time plan times 1.5.

Run sequences The simulation is first run only with the commuter population until the outcome seems stable, in this case for 500 iterations. In each iteration, 10 % of the virtual persons can choose a new route, while departure time and mode stay at their initial values. The outcome is used as a base case for the football scenario where in addition to the commuters also the traffic induced by football fans is simulated. This is run for one iteration with a varying number of football fans, which is is incremented from 0 up to 2000 in steps of 100. The football fans take the shortest route on an empty network to the stadium as it would be suggested by those commercially available navigation devices that do not include real time congestion information.

The above sequence, i.e. 500 iterations followed by one "football" iteration, is performed with three different signal control strategies: In a first simulation sequence, all traffic signals are switched off. This can be used as a lower bound for results concerning signal control since it assumes that vehicles are able to traverse a crossing without any accident, i.e. they are able to drive "through each other". The next sequence uses a fixed-time setup. In the third, final, sequence, all traffic signals are controlled by SYLVIA.

RESULTS

Fig. 3(a) shows the average travel time of all travellers, i.e. of fans plus commuters, in the football scenario as a function of the number of simulated football fans. The beginning of the three curves at zero football fans

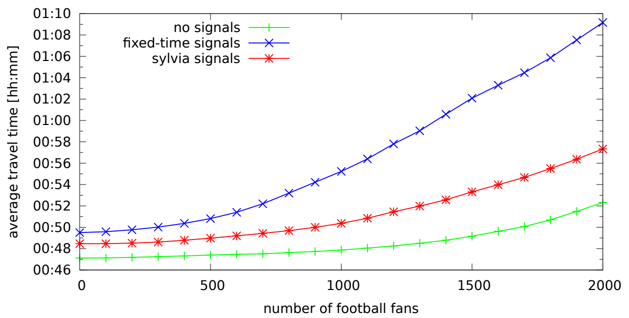
[4] see www.openstreetmap.org

[5] http://www.fcenergie.de/verein/stadion/home.php, last access 14.02.2011

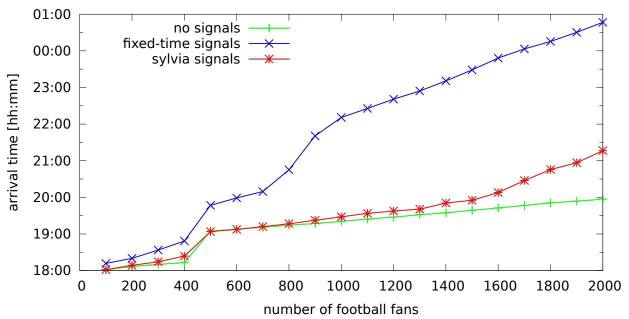
[6] http://www.ssb-cottbus.de/sportstaetten/sdf/, last access 14.02.2011

depicts the effect of the different signal control policies for the pure commuter scenario. Note that it is by no means clear that a traffic-actuated signal strategy will offer a better performance than a fixed-time strategy when the demand is adaptive to the signals. In the situation here, average travel time is about 49.5 min for fixed time control and 48.5 min if SYLVIA is used, that is, the traffic-actuated strategy is indeed better than the fixed time strategy even when the demand can adapt over the iterations. For comparison, the average travel time is 47.1 min in the benchmark when signals are switched off.

With a growing number of football fans, the difference of average travel time increases for the different signal control strategies. If 2000 fans are traveling to the game, the avg. travel time reaches 69.1 min with fixed-time control, 57.3 min with SYLVIA, and 52.3 min when signals are switched off.



(a) Average travel times of all persons over the number of fans driving to the football match.



(b) Arrival time of the last fan at the stadium over the number of fans driving to the football match.

Fig. 3: Results for a varying number of football fans. Green datapoints depict a scenario where traffic lights are switched off, blue datapoints a scenario with fixed-time signal control and red datapoints a scenario in that signals are controlled by SYLVIA.

The effects of the signal control strategy on the avg. travel time are also reflected by the arrival time of the last fan at the stadium that is depicted in Fig. 3(b) over the number of simulated football fans. With up to 400 fans coming to the match, the arrival time difference is approx. 25 min between fixed-time and SYLVIA signal control. If more than 400 fans are coming to the match, this rises quickly. With 2000 fans, the arrival time difference has reached 3.5 hours.

The results indicate that SYLVIA performs better than a fixed-time control with all simulated demand patterns, which is an expectation regarding to traffic-actuated signal control strategies. Beyond that, the stability of the system is not affected in any of the simulated situations.

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