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Transportation Research Procedia 22 (2017) 325–334

Transportation Research Procedia

www.elsevier.com/locate/procedia

19th EURO Working Group on Transportation Meeting, EWGT2016, 5-7 September 2016, Istanbul, Turkey

Intelligent Traffic Lights: Green Time Period Negotiaton

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Abstract

This paper presents a person-based traffic signal control strategy for isolated intersection, including simultaneously signal plan design and signal timing optimization with real-time information on the network dynamics. In order to update the traffic signal control plan, a model of efficient allocation of an available resource (green time period) to consumers (traffic lights) was devised as a protocol to decide who gets the right of using the resources based on an auction-like schema. Traffic streams participate in such an auction to get the right of consuming a certain amount of the available resource and the intersection-control system mediates between traffic streams with opposing goals (conflicting movements). Whereas the decision is to terminate the actual green time, the green time can be assigned to any phase of the traffic signal plan. The selected phase is the one that gives the most benefic contribution for the intersection performance. Decision is formulated to minimize the total person delay at the intersection and consequently assign priority to vehicles with more passenger occupancy, also taking into account the pedestrians. In a social management perspective it should be more important and valuable to minimize "people's" delays or other person-based measure instead of vehicle-centric values. A real four-arm intersection with a time varying origin-destination demand example is tested to demonstrate the proposed method. The paper contributes to the development of a new traffic signal control strategy which breaks with the traditional concepts of traffic control such as the cycle length, the maximum green period and fixed phase sequence. Results reveal that the proposed signal control system reduces total person delay at the intersection and effectively provides priority to vehicles with more occupancy. The system structure is flexible and able to adapt traffic control decisions to predictions and react to unexpected traffic events.

Peer-review under responsibility of the Scientific Committee of EWGT2016.

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2214-241X
Peer-review under responsibility of the Scientific Committee of EWGT2016.
10.1016/j.trpro.2017.03.039

Keywords: Adaptative traffic signal control; green light period, negotiation; auction; multi-agent system

1. Introduction

In the last decades automobile fleets in urban areas have been increasing all over the world bringing serious congestion problems to large cities, affecting them at both social, economic and environmental levels. Conflicts among multiple transport modes (e.g. pedestrian, cars) that share the same space further exacerbate this problem. However, multimodal systems are essential for sustainability of cities. In view of the fact that travel demand increases at a greater rate than the addition of new road capacity and transportation technology evolution, this problem will continue to increase unless an efficient traffic management strategy is implemented. However poor traffic signal control without policy goals in resolving conflicts for shared space, while mitigating congestion can be the responsible for such increasing mobility problems. These systems are traditionally optimized by minimizing total delays for vehicles, thus ignoring the importance of person mobility in networks served by multiple transportation modes. In addition, such vehicle-based optimization can lead to unfair treatment of high occupancy vehicles and their passengers, which contains the applicability of more recent management strategies. In some cities priority schemes for public transport (PT) vehicles was applied, but the real occupancy of the vehicle is not considered. This work intends to go beyond the PT priority and consider the occupation of any vehicle.

In this paper, a person-based traffic responsive signal control system is presented for isolated intersections. The traffic signal control includes simultaneously signal plan design and signal timing optimization with real-time information on the network dynamics. One of the most important topics in traffic signal control is to maintain the traffic system optimized. Basically, after designing the best suitable signal traffic control given a demand it is necessary to update the system according to the demand throughout the day reacting either to slight differences of demand or to significant fluctuations that can occur even within short periods of time due to incidents, even within periods when demand is normally constant. In such cases, the operation of traffic signal control with low flexibility strategies may reflect a sub-optimal operation.

Multi-Agent Systems (MAS) have become a popular paradigm for exploring intelligent solution to traffic management problems. Traffic control is a geographically distributed paradigm, which takes place in a dynamic environment and where interactions between components are highly complex (Rossetti et al., 2008) (Bo and Cheng, 2010). For this characteristics, MAS was selected for designing the traffic signal control (Vilarinho et al., 2015).

This paper proposes a new auction-based intersection-control mechanism allowing for concurrency between all traffic streams of intersection including pedestrian crossings. The traffic signal control should yield a high degree of concurrent utilization of the intersection considering all traffic streams and at the same time prevent vehicles from colliding.

The outline of this paper is as follows. Section 2 is the background, containing a brief literature review of multi-agent negotiation. In section 3, the proposed traffic signal control is described. In section 4, the simulation study results of a single intersection are presented. In section 5, conclusions and future work directions are discussed.

2. Background

The most relevant works in this field of multi-agent negotiation are the ones by Dresner and Stone (2005) (2009), Vasirani and Ossowski (2009) (2011) and Schepperle and Bohm (2008). All these works consider each vehicle (driver) as an agent taking part in the auction.

The former, by Dresner and Stone, presents a mechanism called “reservation-based”, where each driver (an autonomous agent vehicle) approaching the intersection requests the intersection manager for a reservation of “green time interval” to cross the intersection. The intersection manager decides whether to accept or reject requested reservations according to a first-come-first-served strategy and does not feature valuation-awareness.

The second work, by Vasirani and Ossowski, extends the first mechanism to network intersections. The approach is called market-based, in which driver agents (buyers) trade with the infrastructure agent (sellers) in a virtual marketplace, purchasing reservations to cross intersections. The market rules were designed to support “global profit” (revenues from the infrastructure use) with the “social welfare” (e.g. average travel time). The work by