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Poster

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Abstract

An important element in urban traffic management is the Intersection Management (IM) that deals with traffic lights signaling (either real or virtual). Intersections are vulnerable to traffic congestion and accidents. Therefore, this paper investigates a synchronous intersection management protocol for mixed autonomous and human-driven vehicles in the context of decentralized traffic management.

An Intersection Management Protocol for Mixed Autonomous and Legacy Vehicles

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Abstract
An important element in urban traffic management is the Intersection Management (IM) that deals with traffic lights signaling (either real or virtual). Intersections are vulnerable to traffic congestion and accidents. Therefore, this paper investigates a synchronous intersection management protocol for mixed autonomous and human-driven vehicles in the context of decentralized traffic management.

Author Keywords. Intelligent Transportation System, Intersection Management, and Vehicular Ad hoc Networks.

1. The Context and Motivation

The United Nations (UN) 2018 report on urbanization states that by 2050, the urban population will represent 68% of the worldwide population. Urban traffic management is one of the major challenges to be tackled for guaranteeing users' safety, because of the threats created by urban traffic. The time spent in traffic congestion hit the worldwide GDP growth (0.8% in 2013) because of the loss of working hours and harmful effect on the environment (i.e., the emission of CO_2) due to fuel wastage. Approximately 2.5 million accidents occur every year at road intersections. Moreover, the emergence of self-driving or autonomic vehicles creates the opportunity to use information and communication technologies (ICT) to manage all sorts of traffic, i.e., the Intelligent Transportation System (ITS), thus improving intersection throughput while enforcing user's safety. The ITS carries out traffic management through the coordination and cooperation of smart vehicles, smart road infrastructures, wireless sensor networks, etc. Therefore, autonomous intersection management (AIM) seems a good target for improvements, acting adaptively on traffic light signal duty cycles, tracking actual demand for increasing fluidity and maximizing throughput. However, the highest throughput must be achieved while guaranteeing safety by mutual exclusion of contention areas.

2. Related works

With the advent of autonomous cars, several authors studied controlling the vehicles' speeds and positions so that they arrive at the intersection in a collision-free pattern, thus avoiding the need for traffic lights. For example, the work in (Wu 2012) uses an ant colony system, the work in (Azimi 2015) proposes the ballroom intersection protocol while the work in (Aoki 2017) presents a configurable synchronous intersection protocol. Still, several approaches considered traffic lights, e.g., the cooperative and integrated vehicle and intersection control for energy efficiency (Hou 2018). One relevant aspect is that, as experts and scientists anticipate, the transition to an ITS of autonomous vehicles, will not occur before 2045 (Bansal 2017). Therefore, there is a need to support scenarios with mixed autonomous and human-driven vehicles coexisting on the roads (Sharon 2017, Barthauer 2019). Hence, we believe there are still several open problems in mixed vehicle scenarios, particularly space for improving global throughput and reducing crossing latency. Hence, we proposed a synchronous intersection protocol for grid-based autonomous intersection management.

3. Synchronous Intersection Protocol

A four-way single lane intersection including road lanes is divided into equal-sized grid cells as in Fig.1. Each cell can fit a vehicle and some space around it. Multi-Agent System (MAS) based communication model can be employed for coordination among autonomous vehicles (AVs), Human-driven vehicles (HVs), roadside units (RSUs), traffic light controllers (TLCs), and position sensors (P1, P2, and P3). Standard assumptions were considered as in (Aoki 2017) for AVs (yellow color) and HVs (white color) with sensing capabilities. AVs access the intersection with a response message from TLC, while HVs access with TLC green lights. The synchronous intersection protocol works in three steps, detection of HVs among AVs and their relative physical locations, the safety distance between vehicles and their arrival patterns, and intersection crossing time.

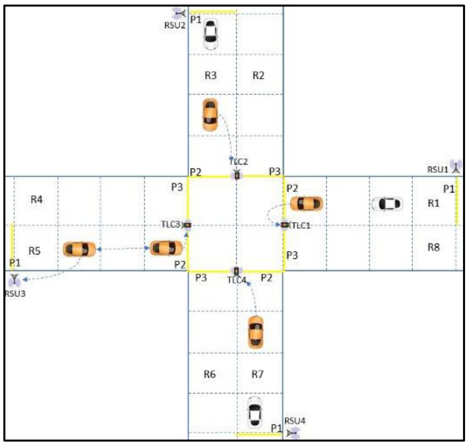

Figure 1: Grid-based Autonomous Intersection with MAS Communication.

AVs send a request message to RSU when entering the road lane (grid area). The RSU sends the count $C_{r,t}$ message (unique number of requests) to TLC in a timely manner. The position sensors P1 and P2 identify the number of vehicles $N_{r,t}$ between them. Therefore, at time t, on any road lane *r*, if the condition $N_{r,t} > C_{r,t}$ is satisfied then there exist HVs on road lanes. Thus, the equation $N(t) - C(t)$ enumerates the total number of HVs on their respective road lanes. The relative physical location of the i^{th} vehicle is $xd + d_s/2$, when a vehicle is identified in between P1 and P2, with x being the number of cells, d the cell width, and d_s is the safety distance that must be kept between vehicles within the intersection. We propose spatio-temporal conditions for maintaining safety distance between vehicles within the intersection. We noted that vehicles cross the intersection without stopping before the intersection if the distance between consecutive vehicles is $2d$ (i.e., arrival pattern). Finally, an intersection crossing time is estimated based on vehicles speed *v* and turning direction, that is, τ for a right turn, 2τ for the straight exit, and 3τ for the left turn with $\tau = {}^{d}/_{v}$.

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