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Intelligent Traffic Signal Control System For V2V/V2I Communication Using Vehicular Ad HOC Network

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Abstract
In this paper, we propose to use vehicular ad hoc networks (VANETs) to collect and aggregate real-time speed and position information on individual vehicles to optimize signal control at traffic intersections. We first formulate the vehicular traffic signal control problem as a job scheduling problem on processors, with jobs corresponding to platoons of vehicles. Under the assumption that all jobs are of equal size, we give an online algorithm, referred to as the oldest job first (OJF) algorithm, to minimize the delay across the intersection. We prove that the OJF algorithm is 2-competitive. We then show how a VANET can be used to group vehicles into approximately equal-sized platoons, which can then be scheduled using OJF. Our simulation results show that, under light and medium traffic loads, the OAF algorithm reduces the delays experienced by vehicles.

Keywords
Online job scheduling, traffic signal control, vehicular ad hoc network (VANET) simulation.

I. Introduction
INTELLIGENT traffic signal control has been extensively studied in the literature. Current methods of implementing intelligent traffic signal control include roadside sensors, such as loop detectors and traffic monitoring cameras. Loop detectors can only detect the presence or absence of vehicles, which is a serious limitation. More recently, video-based traffic detection systems employing traffic monitoring cameras have been considered for traffic signal control, where traffic data from video cameras is aggregated, and duration of red lights are adjusted based on current traffic volumes [1, 2].
In this paper, we examine the possibility of deploying an intelligent and real-time adaptive traffic signal controller, which receives information from vehicles, such as the vehicle's position and speed, and then utilizes this information to optimize the traffic signal scheduling at the intersection.
Vehicles can use wireless communications for vehicle-to -vehicle (V2V) or vehicle-to-infrastructure (V2I) communications, as described in the short-range communications/wireless access in vehicular environments standards operating in the spectral range of 5.85–5.95 GHz. We refer to the transient mesh networks formed via V2V or V2I communication links as vehicular ad hoc networks (VANETs).

II. Algorithm

A. 2-Competitive Algorithm for Job Scheduling
Having made the reduction from vehicular traffic scheduling to job scheduling with conflicts, we present a 2-competitive algorithm that minimizes latency for each job that we call the OJF scheduling algorithm.
Algorithm 1: OJF scheduling algorithm.
Let a^r_i, a^r_j, a^l_k and a^{l1}_m be the earliest arrival times on each of the vertices of G^1;
while *r, r^1, l, l^1 have jobs waiting,* **do**
Let a^s_t be the earliest arrival time among a^r_i, a^{r1}_j, a^l_k, and a^{l1}_m;
Let S be the side of G^1 on which vertex s lies;
for *Each vertex s^1 on side S in G^1*, **do**
Schedule the job with the earliest arrival as^1_t;

B. Platooning Algorithm
The platooning algorithm is an exhaustive search over all the platoon configurations to determine the platoon combination that minimizes the difference between the maximum and minimum GREEN times. Since the vehicles arrive on a leg of the intersection, only a platoon size is required to identify a particular platoon.

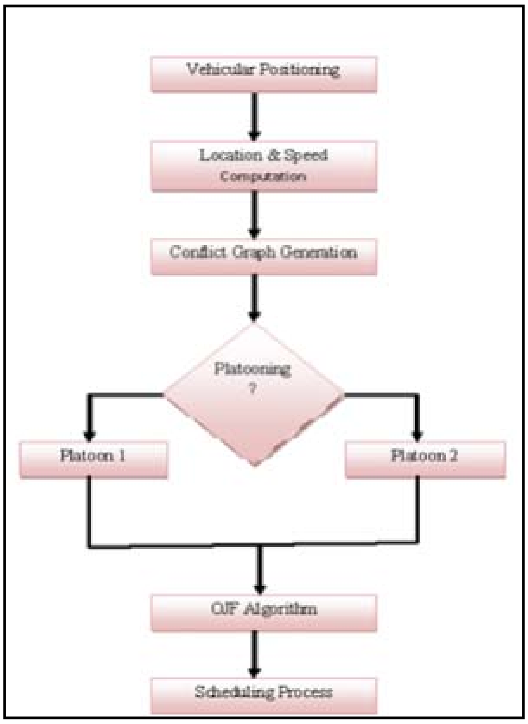

Fig. 1: Platooning Flow chart

Algorithm 2 Platooning Algorithm
for *each approach k* **do**
Configuration = IntegerPartitions(n)
for *each platoon configuration i in Configuration* **do**
for *each platoon j in i* **do**
Platoon_Green_Time[j] =

Estimate_Green_Time(j);
Add Platoon_Green_Time[j] to the list
Config_Green_Time[i, k];
Min_Diff =
$\min_{i\in k, k=\{1,...,4\}}$
$\{\max\{$Config_Green_Time[i, k]$\}$ −
$\min\{$Config_Green_Time[i, k]$\}\}$;
Final_Platoon_Configuration =
$\mathrm{argmin}_{ik, k=\{1,...,4\}}\{\max\{$Config_Green_Time[$i$,$k$]$\}$
$-\min\{$Config_Green_Time[i, k]$\}\}$;

III. Simulation Model

We have developed a simulator that integrates a vehicular traffic simulator and a wireless network simulator to produce a closed-loop simulation environment. The vehicular traffic simulator is the TCL scripter traffic simulator [3], [5], which is a space continuous microscopic simulator for vehicular traffic. The TCL scripter simulator is a C++-based open-source highly portable microscopic road traffic simulation package designed to handle large road networks. The underlying vehicular traffic model has been validated. The wireless network simulator is the NS2-simulator [4] wireless network simulator, which is a component-based modular open-architecture discrete-event network simulator implemented in C++.

We have extended NS2-simulator with a module that allows creation of new nodes as vehicles are injected into TCL scripter, deleting nodes when their corresponding vehicles reach their destination and reflecting the movement of their corresponding vehicles in TCL scripter. Therefore, in our implementation, the data aggregation module encapsulates the adaptive traffic signal control algorithms for the traffic lights. The timing sequence diagram of these events is shown in Fig2. NS2-simulator also uses the TCL interpreter to send the vehicle control information in the form of TCL interpreter commands.

NS2-SIMULATOR TCL-interpreter TCL-scripter

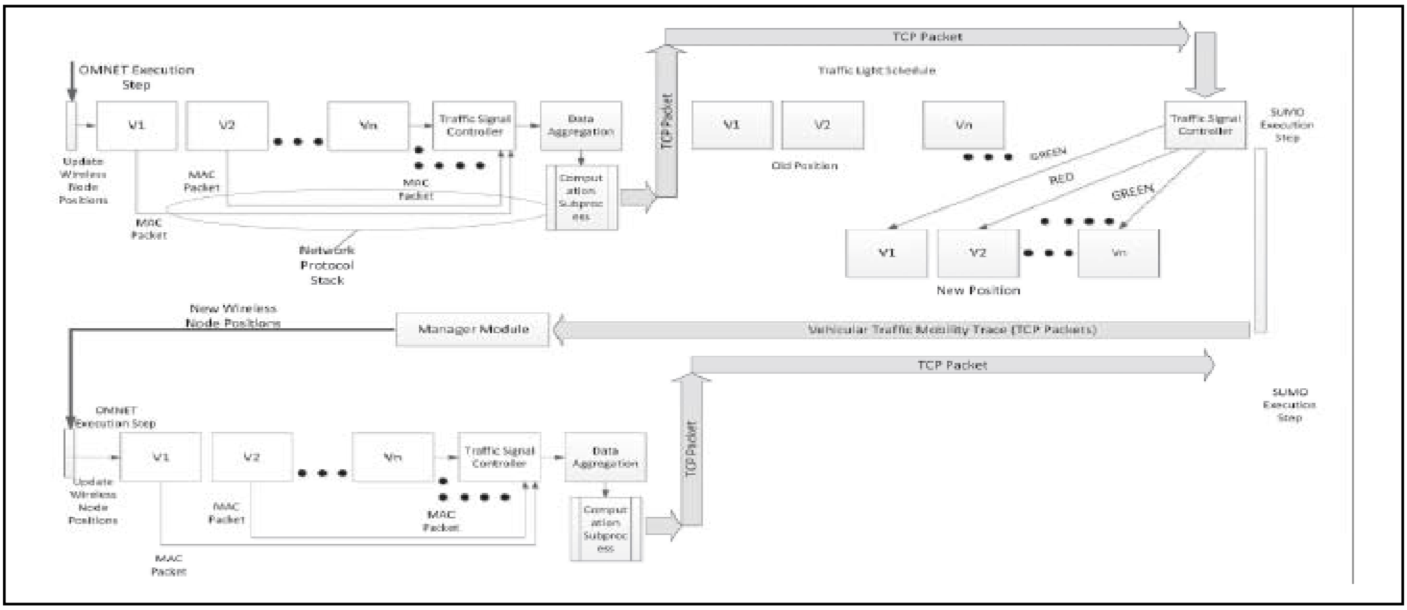

Fig. 2: Sequence diagram of TCL-interpreter message exchange between TCL-scripter and NS2-simulator.

IV. Results And Discussion

We compare the performance of the OAF algorithm against the VANET-enabled vehicle-actuated control, VANET-enabled Webster's method, and an optimized fixed time signal control. For the fixed-time approach, the controller has been optimized for the current traffic parameters, following the guidelines in [7]. The timing parameters were 60 s of GREEN for the through traffic and 30 s of GREEN for the left turning for the heavy traffic condition, 40 s of GREEN for the through traffic and 20 s of GREEN for the left turning traffic for the Medium traffic condition, and 35 s of GREEN for the through traffic and 15 s of GREEN for left turning traffic for the light traffic. We also tested the effectiveness of the platooning algorithm, which is part of the OAF signal control algorithm.

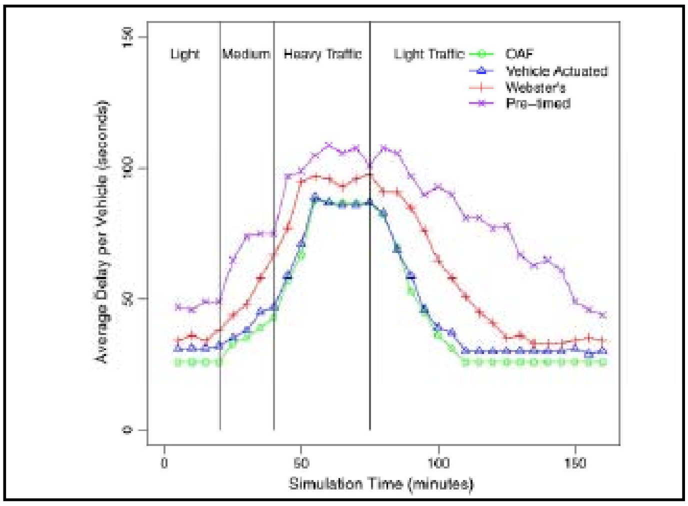

Fig. 3: Performance of OAF algorithm compared with other VANET-based traffic signal scheduling methods when all four approaches have equal vehicle arrival rates.

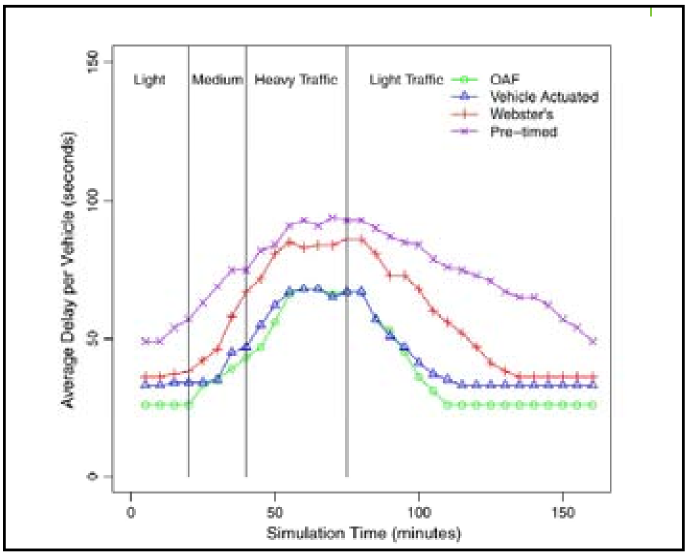

Fig. 4: Performance of the OAF algorithm compared with other VANET based traffic signal scheduling methods when north–south approaches have constant (800 vehicles/hour) arrival rates and east–west approaches have a varying vehicle arrival rate.

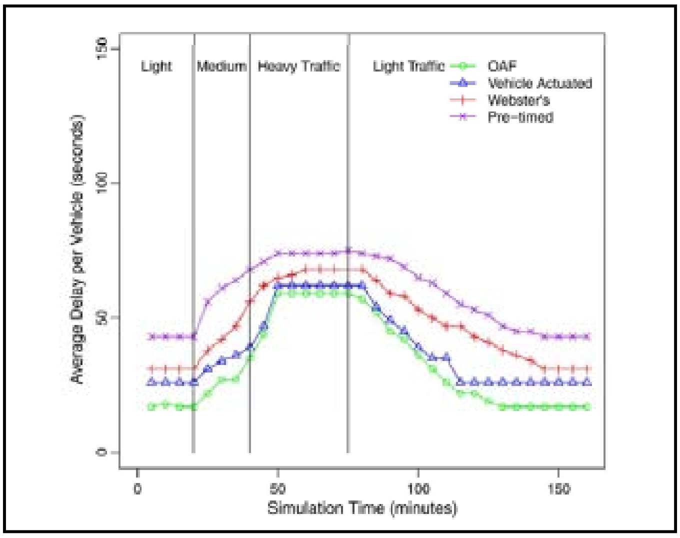

Fig. 5: Performance of the OAF algorithm compared with other VANET based traffic signal scheduling methods when north–south approaches have constant (100 vehicles/hour) arrival rates and when the east–west approaches have a varying vehicle arrival rate.

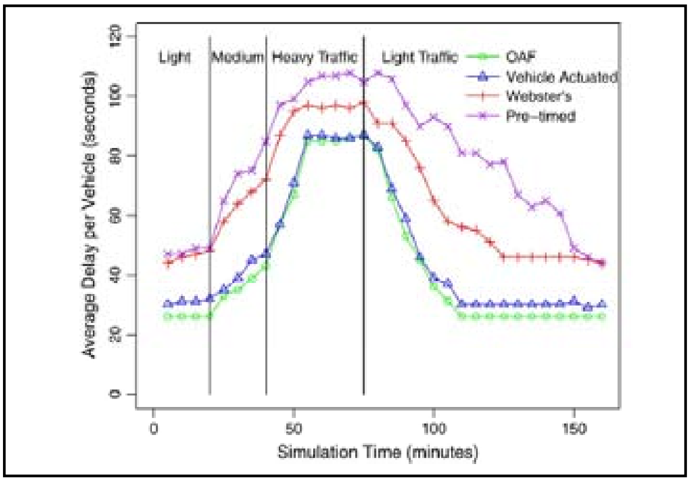

Fig. 6: Performance of the OAF algorithm compared with other VANET based traffic signal scheduling methods when all four approaches have equal vehicle arrival rates, and the arrival process is modeled by a uniform arrival process.

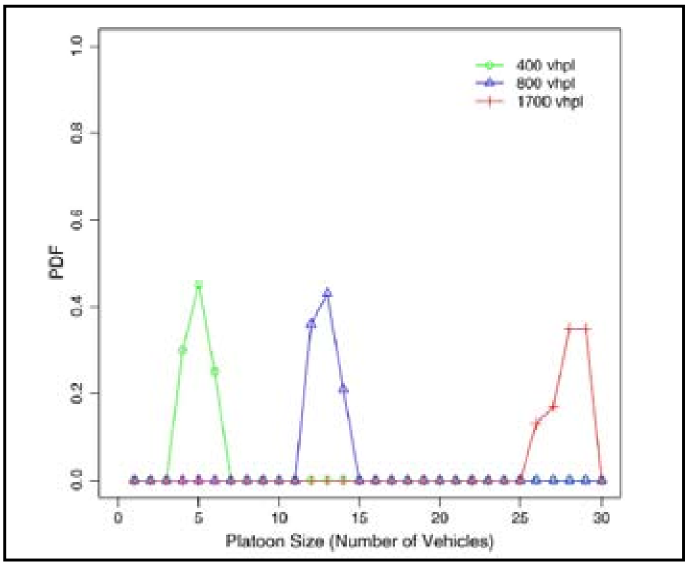

Fig. 7: Platoon size distribution under identical traffic arrival rate.

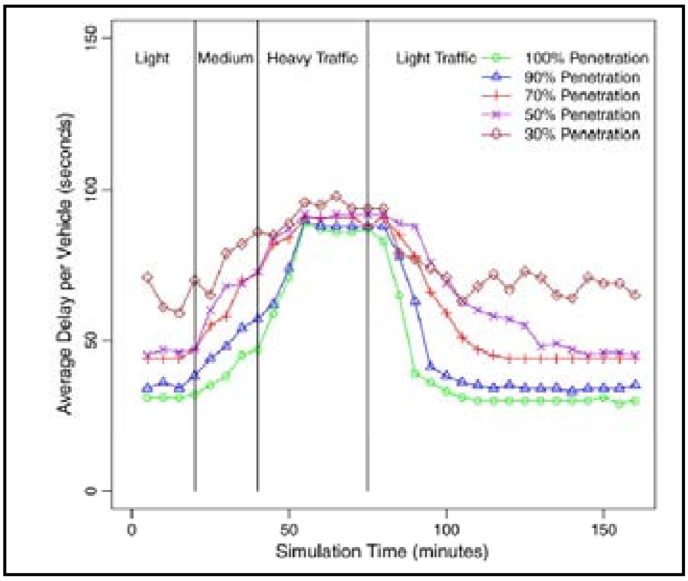

Fig. 8: Average delays produced by the OAF algorithm under various penetration rates.

V. Conclusion

In this paper, we have shown how a VANET can be used to aid in traffic signal control, including a new job scheduling based online algorithm, i.e., the OAF algorithm. We implemented several adaptive traffic signal control algorithms that use the fine grain information broadcasts by the vehicles. We implemented and compared these algorithms under various traffic conditions. Our experimental results show that the OAF algorithm reduces the delays experienced by the vehicles as they pass through the intersection, as compared with the other three methods under light and medium vehicular traffic loads. Under heavy vehicular traffic load, the performance of the OAF algorithm degenerates to that of the vehicle-actuated traffic method but still produces lower delays, compared with Webster's method and the pretimed signal control method.

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