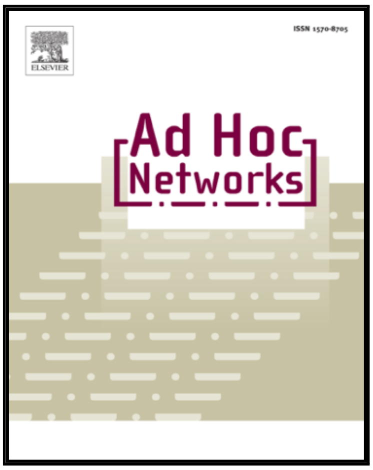
Accepted Manuscript



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PII: S1570-8705(18)30616-4
DOI: https://doi.org/10.1016/j.adhoc.2018.08.018
Reference: ADHOC 1748

To appear in: *Ad Hoc Networks*

Received date: 1 March 2018
Revised date: 13 June 2018
Accepted date: 29 August 2018

Please cite this article as: Izhak Rubin, Andrea Baiocchi, Yulia Sunyoto, Ion Turcanu, Traffic Management and Networking for Autonomous Vehicular Highway Systems, *Ad Hoc Networks* (2018), doi: https://doi.org/10.1016/j.adhoc.2018.08.018

Traffic Management and Networking for Autonomous Vehicular Highway Systems

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Abstract

We develop traffic management and data networking mechanisms and study their integrated design for an autonomous transportation system. The traffic management model involves a multi-lane multi-segment highway. Ramp managers regulate admission of vehicles into the highway and their routing to designated lanes. Vehicles moving across each lane are organized into platoons. A Platoon Leader (PL) is elected in each platoon and is used to manage its members and their communications with the infrastructure and with vehicles in other platoons. We develop new methods that are employed to determine the structural formations of platoons and their mobility processes in each lane, aiming to maximize the realized flow rate under vehicular end-to-end delay constraints. We set a limit on the vehicular on-ramp queueing delay and on the (per unit distance) transit time incurred along the highway. We make use of the platoon formations to develop new Vehicle-to-Vehicle (V2V) wireless networking cross-layer schemes that are used to disseminate messages among vehicles traveling within a specified neighborhood. For this purpose, we develop algorithms that configure a hierarchical networking architecture for the autonomous system. Certain platoon leaders are dynamically assigned to act as Backbone Nodes (BNs). The latter are interconnected by communications links to form a Backbone Network (Bnet). Each BN serves as an access point for its Access Network (Anet), which consists of its mobile clients. We study the delay-throughput performance behavior of the network system and determine the optimal setting of its parameters, assuming both TDMA and IEEE 802.11p oriented wireless channel sharing (MAC) schemes. Integrating these traffic management and data networking mechanisms, we demonstrate the performance tradeoffs available to the system designer and manager when aiming to assure an autonomous transportation system operation that achieves targeted vehicular flow rates and transit delays while also setting the data communications network system to meet targeted message throughput and delay objectives.

1. Introduction

Autonomous driving is taking momentum at a vastly growing pace. Early implementations for various applications, such as taxi services [1], are being introduced. A full understanding of large scale deployment of systems of autonomous vehicles is a key component of a safe growth of the Intelligent Transportation Systems (ITS) as a critical component in the development of a paradigm for the architecture of the next generation smart city. A wide range of mechanisms, technologies and regulation procedures need to be developed and enacted under this perspective, including technical, legal, economic and social impact factors.

Among the multitude of technical aspects that dominate the design, management and control of high performance autonomous driving systems, the following two elements are of paramount importance: vehicular traffic management and data networking – the latter involving communications and data dissemination among vehicles, i.e. Vehicle-to-Vehicle (V2V), and between vehicles and fixed infrastructure, i.e. Vehicle-to-Infrastructure (V2I). A common characteristic of these traffic management and data communications networking elements is that they address coordination and reliable interactions among distributed entities, moving in space and time, at a potentially large scale. For the specific case of autonomous driving, the inter-dependence of those two components are stronger than ever. High performance reliable communications networking of data messages among moving vehicles is a key ingredient in enabling the learning by autonomous vehicles of their surrounding environment, the rapid reaction to critical events assure the safety of the operation, coordination among vehicles to synchronize mobility and maneuvering. They also aid in the execution of processes that serve to optimize travel safety, reduce transit delays, disseminate sensed data reports to nearby vehicles that include envi-

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