EE299 Project Course

Vehicular Ad Hoc Networks (VANET)

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# Routing in Sparse Vehicular Ad Hoc Wireless Networks

Authors: Nawaporn Wisitpongphan, Fan Bai, Priyantha Mudalige, Varsha Sadekar, and Ozan Tonguz

## Introduction

This paper focuses on a specific case of a Vehicular Ad Hoc Network (VANET) where a fully connected network infrastructure may not be present. In a real world setting, the availability of relay towers or other vehicles capable of relaying information may not be in range or not present at all. In the article “Routing in Sparse Vehicular Ad Hoc Wireless Networks”, the assumption is that a communication network will be fragmented and sparse at times and the models and frameworks developed will take into account the varying vehicle densities and market penetration of a given network system. By using this assumption the models developed to describe network behavior given varying vehicular densities are proven to be acceptably accurate by comparing the analytical results against multiple Monte Carlo simulations as well as data collected from empirical studies of real world traffic scenarios.

## Describe Problem

Much research is devoted to developing routing algorithms and protocols for communication between vehicles in a dense network setting or resolving the issue of broadcast storms. Although this is a valid scenario it does not include scenarios where the connectivity of a network may not be reliable such as in rural areas or late night traffic situations where it may not be possible to maintain a connected network. The research set forth will instead focus on the situation where a consistent connected network is not always feasible and develop models that incorporate network fragmentation into the solution.

Focusing on the fact that any particular VANET will at times experience network discontinuity three key questions must be answered:

1. What are the consequences when trying to relay safety messages to other vehicles when the network is constantly disconnected?
2. In a disconnected VANET what are the key characteristics to observe and what are the adverse effects on performance in the network?
3. What is the solution to a disconnected VANET if any? And if there is not a viable solution to this problem how can the affects of network fragmentation become minimized?

In this paper, not only will it highlight the reality of network fragmentation in real world settings, it will also introduce a possible solution to the disconnected network issue. The solution proposed, “Stored-carry-forward” mechanism, will prove to be viable through analytical and simulation results, as well as comparing with empirical data collected by the Berkeley Highway Laboratory (BHL).

The BHL research is vital to proposed model because it realistically influences important parameters of the model such as inter-arrival time and inter-vehicle spacing between vehicles. For example through the empirical studies the results showed that inter-vehicle spacing follows an exponential distribution when the traffic volume is below 1000 vehicles/hour. Furthermore, with the assumption that all vehicles possess the technology of wireless communications, the network still experienced network discontinuity of up to 35% during hours of low traffic volume.

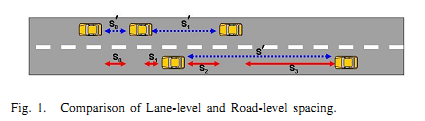
## Proposed Model

The foundation of this model is based on a well known model, the Car following model. This model assumes a single-lane scenario with any type of traffic conditions. Another assumption is that drivers drive safely and that drivers’ deceleration factors are taken into consideration. The model is shown below:

|  |  |
| --- | --- |
|  | * S’ - headway spacing between rear bumper to rear bumper * L - effective vehicle length in meters * - driver reaction time in seconds * V - vehicle sped in meters/second * - reciprocal of twice the max average deceleration of a following vehicle (ie approximately 0.075 ) |

To simplify the model, with the “good-driver” assumption. This assumes that every driver will have a similar deceleration factor which simplifies the above the original equation to:

The car following model describes adjacent vehicles that are travelling in the same lane. From a network perspective, it is irrelevant whether the following car is in the same lane or next because our focus is network connectivity, which depends more on the distance away from a particular vehicle regardless of position. Because of this the model is expanded to represent a multi-lane system. Below we observe the distinction between a single-lane (blue arrows) and multi-lane (red-arrows) model. The arrows in blue are only associated with vehicles directly in the same lane where as the red arrows are associated with the next closest vehicle in proximity.



Another adjustment that needs to be made is with (the driver reaction time). Through raw data collection during moderate to light traffic, was as large as 50-100 seconds. This is unrealistically high as a representation for driver reaction time, so instead will replace as the inter-arrival time of vehicles. The final adjustment is the minimum spacing L. Because of the multi-lane configuration we expand L to to represent the minimum distance between any 2 vehicles regardless if they are in the same lane (red arrows). The new model then becomes:

|  |  |
| --- | --- |
|  | * – road level inter-vehicle spacing * - minimum spacing between any two adjacent vehicles * - inter-arrival time of vehicles on any lane from fix observation point * V - vehicle sped in meters/second |

This model is now capable of characterizing traffic conditions in both heavy and light traffic situations. The next step to making this model more tangible is to correctly or approximately calculate the inter-arrival time and vehicle speeds. We can leverage the data collected by BHL to approximate these two parameters to give realistic values for in different traffic situations.

## Empirical Research Results

The basis of the proposed research solution is based heavily on empirical data collected in a real world environment. The data was collected by BHL on the eastbound I-80 five lane freeway on June 27, 2006 for a time span of 24-hours with a recording frequency of 60 recordings per second. Given the measurements it is possible to approximate the inter-arrival times and average vehicle speeds for different traffic conditions. To better represent vehicular traffic conditions three different time periods are used to distinctly represent three varying conditions. 1am-3am models sparse traffic conditions where vehicles are traveling at higher speeds, 10am-12pm represents moderate traffic conditions and average speed, and 3pm-5pm will be the case of rush hour where vehicles are tightly packed traveling at low speeds. Figure 2 and 3 are the results charting the vehicles/hour (traffic density) and speed of vehicles against the time of day.



From the data in figure 2 and 3 the inter-arrival time and the average vehicle speed V can be approximated for the three different vehicle density scenarios. Graphing the results of the extrapolation we can see that the inter-arrival time can be closely approximated by an exponential distribution during the early morning period while the speed of vehicles resembles a normal distribution. Because this research is centered on the notion that a network will inevitably be fragmented we will emphasize the results between 1am-3am which most closely represents a network that will display sporadic connective behavior. Figure 4 shows the Probability Density Functions (PDF) of both the inter-arrival times and vehicle speeds. Particularly figure 4(a) will be of high value in aiding to determining



## Solution

First we must define what is meant by disconnection from the network. We will consider two vehicles to be network disconnected if their distance is greater than 250 meters.

## Analysis

## Performance Results

## Discuss Results

## Suggestion

# References

## [1] Routing in Sparse Vehicular Ad Hoc Wireless Networks

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