Biologically Inspired Solutions to Fundamental Transportation Problems

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Introduction:

Traffic congestion in urban areas is an acute problem which is getting worse with the increased urbanization of the world population. The existing approaches to increasing traffic flow in urban areas have proven inefficient as they are expensive and therefore not scalable. It is therefore clear that one needs a new and radically different approach to solve this problem.

In the paper, we argue that such a revolutionary approach exists and draws its inspiration from social insect colonies in nature such as ants, bees, and termites as well as other self-organizing biological systems, such as birds and fish. This vision leverages the new vehicle-to-vehicle (V2V) communications capability of modern vehicles based on dedicated short-range communications (DSRC) technology, which allows the vehicles to communicate with each other and behave as a self-organizing network, very much like self-organizing biological systems.

We propose to migrate infrastructure-based traffic lights to in-vehicle traffic lights, which will enable cars to create “virtual traffic lights” at intersections and manage traffic without the use of infrastructure-based traffic lights. It is shown that this biologically inspired approach can increase traffic flow rates by about 60 percent during rush hours in major urban areas.

Motivation:

The urbanization of the world population has increased dramatically in the last two decades and now more than half of the world population lives in cities [1]. This phenomenon will clearly continue in the foreseeable future as the underlying socio-economic reasons for it are quite compelling. It is thus clear that the acute transportation problems we are facing today (such as congestion, pollution, energy efficiency, etc.) will get worse in the next 20-30 years [2], [3]. A careful study of the aforementioned problems reveals that these problems are interrelated and intertwined. It is therefore important to have a powerful approach through which most, if not all, of these problems can be addressed simultaneously. Information technology (IT) appears to have this potential.

Approach :

In this proposal, we take the viewpoint that increasing the use of information technology (IT) in future vehicles could solve or mitigate many of the fundamental problems we face today in transportation, energy efficiency, reduced carbon footprint for cars, greener environment, and several others. More specifically, we focus on making vehicles more intelligent and autonomous for increasing safety at intersections, mitigating congestion, reducing the commute time of urban workers, increasing productivity of the USA (as well as other countries), increasing the energy efficiency of cars, reducing the carbon footprint of cars, and supporting a greener environment [1], [3].

Figure 1 : The proposed "Virtual Traffic Lights" concept in animated form [3].

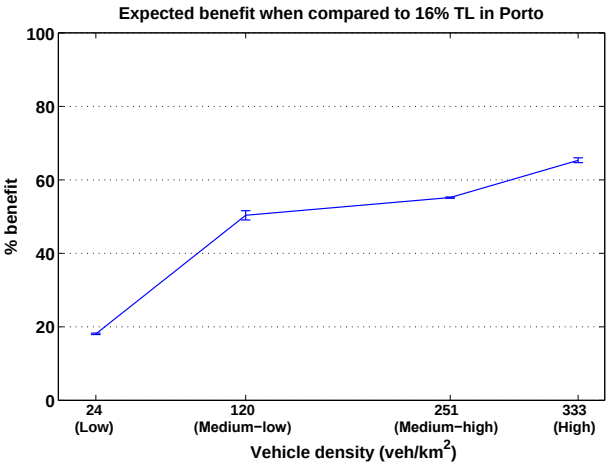

Figure 2: Percentage benefit of the proposed approach in terms of maximizing average traffic flows during rush hours in the city of Porto [1], [3].

In particular, we propose a new technology which migrate infrastructure-based traffic lights to in-car traffic lights, as shown in Figure 1 (as an animation) [3]. Using the emerging vehicle-to-vehicle (V2V) communications capability of modern cars through the DSRC standard at 5.9 GHz, it has been shown that **this technology can make traffic control ubiquitous at every intersection in urban areas**. Through V2V communications, the vehicles at different legs of an intersection can elect a leader which can manage the traffic flow at that intersection, thus acting as a "Virtual Traffic Light". The results of our investigation in the last three years have shown that this technology can reduce the commute time of

urban workers between 40-60% during rush hours (see Figure 2) which seems pretty significant in terms of reducing accidents at intersections, mitigating congestion, increasing productivity, reducing carbon footprint of cars, increasing the energy-efficiency of transportation, and supporting a greener environment.

Statement of Work:

In the next 2 years, we intend to push this technology further by addressing some key issues that will accelerate its adoption. To this end, we will execute the following tasks: (1) We will study how to deal with the "partial penetration" problem of DSRC technology at the initial stages of deployment which is a serious obstacle for the wide-spread use of the envisioned technology; (2) We will develop new technologies which will integrate the presence of pedestrians and cyclists; (3) We will evaluate the performance of the developed technology for real cities through the large-scale simulator the PI and his collaborators have developed; (4) Experimental verification through a test bed with DSRC radios.

Milestones:

Year 1:

1. Quantify the severity of the "partial penetration" problem and generate practical solutions (hardware and software platforms) for addressing the problem (October 2012)
2. Develop new algorithms and technologies that will take into account the presence of pedestrians and cyclists at intersections (December 2012)

Year 2:

1. Develop a large-scale simulator which will be a mobility simulator integrated with a network simulator and assess the performance of the developed solutions (October 2013)
2. Experimental verification of the developed technology through a test bed (Dec. 2013)

Funding:

The proposed project has already attracted $ 2 Million funding since 2009. The CMU start-up Virtual Traffic Lights, LLC, is currently looking for additional funding and investment for pushing this technology further.

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