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Original Research Paper

Evaluation of connected vehicle impact on mobility and mode choice

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ABSTRACT

Connected vehicle is emerging as a solution to exacerbating congestion problems in urban areas. It is important to understand the impacts of connected vehicle on network and travel behavior of road users. The main objective of this paper is to evaluate the impact of connected vehicle on the mode choice and mobility of transportation networks. An iterative methodology was used in this paper where demands for various modes were modified based on the changes in travel time between each origin-destination (OD) pair caused by introduction of connected vehicle. Then a traffic assignment was performed in a micro-simulation model, which was able to accurately simulate vehicle-to-vehicle communication. It is assumed that vehicles are equipped with a dynamic route guidance technology to choose their own route using real-time traffic information obtained through communication. The travel times obtained from the micro-simulation model were compared with a base scenario with no connected vehicle. The methodology was tested for a portion of Downtown Toronto, Ontario, Canada. In order to quantify changes in mode share with changes in travel time associated with each OD pair, mode choice models were developed for auto, transit, cycling and pedestrians using data mainly from the Transportation Tomorrow Survey. The impact of connected vehicle on mode choice was evaluated for different market penetrations of connected vehicle. The results of this study show that average travel times for the whole auto mode will generally increase, with the largest increase from connected vehicles. This causes an overall move away from the auto mode for high market penetrations if a dynamic route guidance algorithm is implemented.

1. Introduction

A vehicular ad hoc network (VANET) uses vehicles as communication points in order to create a wireless network. The connected vehicle (CV) is a system that uses this concept to create a network with two different types of communication. With vehicle-to-vehicle (V2V) communication, vehicles are able to communicate relevant pieces of information with

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each other, while vehicle-to-infrastructure (V2I) allows vehicles to transmit and receive information with infrastructure. Connected vehicle has the potential to improve transportation networks in many ways, including the realms of safety, mobility, environment and entertainment (Genders and Razavi, 2015; Olia et al., 2015). The particular application that this paper will focus on is dynamic mobility through dynamic route guidance, where vehicles are assigned their route based upon the travel times experienced by other vehicles. Providing vehicles with the most recent and direct information about link travel times should enable vehicles to find the fastest route between their origin and destination through a given network. Connected vehicle, through its applications such as dynamic route guidance, has the ability to change the performance of a transportation network. This change in performance will cause travelers to change their decision about what mode to use. Incorporating this change in traveler mode choice provides a more accurate depiction of network performance after the technology is introduced and depicts the new mode share and multimodal demand. The effect that real-time traffic information and dynamic route guidance has on mobility as well as on mode choice will be studied throughout this paper.

Understanding the impact that dynamic mobility in particular dynamic route guidance may have on a transportation network is important for all stakeholders as it allows them to accurately prepare for upcoming changes. The results of this paper can assist a wide range of stakeholders. For those creating the technology, it may impact how information is collected and used, as poor results could lead to a lack of adoption. For managers of the network, understanding potential impacts can allow them to prepare for predicted changes. Policy makers have the ability to create policy that can incorporate the expected changes into their decisions. This paper presents related work and background, depicts the scope of the study, outlines the proposed methodology, and discusses the results.

2. Literature review

Connected vehicle technology enables vehicles to send and receive information in practically real-time. This information is transferred between vehicles and infrastructure, creating a communication network with the technology split into two realms, V2V and V2I. Various types of information can be sent through connected vehicle technology allowing for a vast amount of practical applications. These applications are sensitive to the details of technology including latency, communication range, and market penetration (MP) (Dion et al., 2011).

Areas of application include, but are not limited to, safety, mobility, and environmental sustainability. An area of interest with main relevance to this study is in the realm of increased mobility. Connected vehicles impact mobility through the use of various systems including incident scene detection and alerts (Zhuang et al., 2011), signal priority or reserved-lane priority for transit, emergency vehicle, and freight (Wang et al., 2014), adaptive signals (Feng et al., 2015), ramp metering (Kattan and Saidi, 2013), overall improvement of intersection efficiency (Guler et al., 2014), and strategies to detect and deal with queue spillback (Li et al., 2013). Aside from the auto mode, transit is also a large focus of connected vehicle, including bus operations optimized for signal timings (Ma et al., 2013), dynamic transit operations (He et al., 2011), and various other applications (Huff et al., 2015). Some are even exploring new modes of transportation such as a fleet of deployed vehicles that respond to travelers in real-time (Jung et al., 2015). Others are attempting to detect spillbacks and to adjust signal timing using connected vehicles in order to improve network throughput (Rivadeneyra et al., 2014). Many of these applications have the ability to replace current technologies with potentially more efficient implementations. As an example, connected vehicle technology makes dynamic routing possible with the consideration of real-time traffic status (Ding et al., 2010). Vehicles then make a more informed choice about which route to take in order to minimize their own travel time, which balances transportation networks into a more realistic user equilibrium state utilizing the entirety of the network.

Central to this paper is the use of connected vehicle for dynamic route guidance. Vehicles route through the network using ongoing and real-time information provided to them from other vehicles. This is facilitated through connected vehicle technology. Dissemination of data is critical to vehicles being able to properly use the best routes. In some cases, they can provide travelers with personalized routes, based upon user preferences (Ma et al., 2015). Although there are major challenges such as how to best broadcast messages and deal with security, work has been done to improve these areas (Chen et al., 2011). In some cases, route guidance is proposed in order to solve a specific problem, such as congested off-ramps by diverting vehicles to other ramps to avoid ramp spillback (Spiliopoulou et al., 2014). Many others have sought to improve current route guidance methods by using prediction of future state of a network (Park et al., 2010; Xu et al., 2011), while some are looking at the impact of accurate information (Ben-Elia et al., 2013).

Many multimodal methods of traveler information and route guidance systems have been researched. Researchers have analyzed the attributes that affect transit route choice as well as the decision to take transit (Eluru et al., 2012). However, these studies do not consider route choice through dynamic route guidance or connected vehicles. Tools have been developed that provided travelers with real-time transit information and used this to improve multi-modal trip planning (Zhang et al., 2011) similar to how this study uses real time information for auto users. An advanced traveler information system has been proposed with multiple modes and a focus on pedestrians (Yu and Lu, 2012). The concept of how to use dynamic traffic assignment best for short-term planning such as mode choice has been explored, aimed at presenting a framework for these situations (Sundaram et al., 2011). By a review of the literature, it is apparent that there is a great interest into route guidance as well as routing methods for multiple types of modes. However, how routing, and in particular dynamic route guidance, will effect mode choice, has yet not to be studied. This paper is a start in bridging that gap by exploring how dynamic route guidance can affect mode choice and the performance of transportation networks.