Chapter X

Proactive Traffic Merging Strategies for Sensor-Enabled Cars

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ABSTRACT

Congestion is a major challenge in today’s road traffic. The primary cause is bottlenecks such as ramps leading onto highways, or lane blockage due to obstacles. In these situations, the road capacity reduces because several traffic streams merge to fewer streams. Another important factor is the non-coordinated driving behavior resulting from the lack of information or the intention to minimize the travel time of a single car. This chapter surveys traffic control strategies for optimizing traffic flow on highways, with a focus on more adaptive and flexible strategies facilitated by current advancements in sensor-enabled cars and vehicular ad hoc networks (VANETs). The authors investigate proactive merging strategies assuming that sensor-enabled cars can detect the distance to neighboring cars and communicate their velocity and acceleration among each other. Proactive merging strategies can significantly improve traffic flow by increasing it up to 100% and reduce the overall travel delay by 30%.
INTRODUCTION

Road traffic congestion is a major challenge nowadays. The integration of sensing, communicating, and local computing within cars facilitates new opportunities to optimize road capacity, and thereby reducing traffic congestion. Currently, a variety of automotive sensors are available to collect data related to a vehicle and its surroundings. Communication techniques, such as Dedicated Short Range Communications (DSRC) support the information exchange between cars. Recent research primarily focuses on: safety by reducing traffic accidents based on, for example, collision warnings (ElBatt et al., 2006); traffic flow control to reduce traffic congestion and to increase road efficiency by adapting traffic lights and speed limits (Papageorgiou & Kotsialos, 2002); and automation to reduce a driver’s burden, e.g., using Adaptive Cruise Controls (ACC) (Kesting et al., 2008).

One important cause of congestion is bottlenecks at merging areas where a ramp leads onto the highway. There is a considerable amount of research to address merging strategies, in particular approaches from queuing theory or statistics. This chapter explores the benefits of applying simple traffic control rules at the merging sections assuming all cars are sensor-enabled.

The goal of merging strategies is to mitigate traffic congestion by optimizing the utilization of roads, ensuring road safety. We believe that a promising approach is achieved by sensor-enabled cars using well-informed decisions and cooperating driving. Traditional traffic control approaches such as traffic signal timing, ramp metering, and real-time information can benefit from the sensor-enabled cars and Vehicular Ad hoc NETworks (VANETs).

The rest of the chapter is structured as follows: we first review foundations of strategies to control traffic flow, factors that affect traffic flow, desirable and undesirable characteristics of traffic flow. Next we overview traffic control strategies and examine merging strategies. Then we present the criteria to evaluate merging strategies. Finally, we outline future trends and challenges for traffic control research and conclude the chapter.

BACKGROUND

In this section, we first review current research on traffic models. These models provide the foundation to explore the effects of implementing new traffic control strategies. We argue that the mobility models commonly used in the study of communication ranges and information dissemination in VANETs are not sufficient for investigating traffic control strategies. Then, we review automotive sensors that can be implemented in the sensor-enabled cars. Those sensors collect traffic information as the input for the traffic model applied in traffic control strategies. Finally, we highlight some basic vehicular traffic theory concepts, with a focus on the traffic congestion on highways to provide a better understanding of traffic flow and design the flow control strategy.

Vehicular Traffic Models

Traffic models and simulations provide an understanding of traffic phenomena to manage traffic in such a way that traffic flow is optimized and congestion is alleviated. From a computational perspective, various tools and techniques such as car-following theories and cellular automata have been applied to traffic modeling.

By far the most widely used mobility model is the Random WayPoint model (RWP). This model was first used by Johnson and Maltz (1996), and it has become the de facto standard in mobile computing research, including VANETs.

RWP has several limitations as a model for VANETs. First, it describes the movement pattern of independent nodes, however, the movement of vehicles is not independent as vehicles interact with other vehicles in their vicinity. Second,