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Networked Control Challenges in Collaborative Road Freight Transport

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Abstract

Freight transport is of major importance for the European economy and is growing thanks to increasing global trade. About three quarters of inland freight transport in the European Union is on roads. It has the potential to go through a dramatic change over the next decades thanks to the recent development of technologies such as wireless communication, cloud computing, sensor devices, and vehicle electronics. They enable a new integrated goods transport system based on optimized logistics, real-time traffic information, vehicular communications, collaborative driving, and autonomous vehicles. In this paper, we discuss challenges in creating a more efficient and sustainable goods road transportation system and how some of them can be tackled with a networked control approach. In particular, we discuss a method to improve the efficiency of the transportation system by minimizing the number of empty transports needed to fulfill the assignments on a given road network. Assignments with overlapping route segments might lead to further improvements, as the formation of vehicle platoons yields reduced fuel consumption. For realistic scenarios, it is shown that such collaboration opportunities arise already with relatively few vehicles. The fuel-efficient formation and control of platoons is also discussed. Some of the presented methods have been tested on real vehicles in traffic. The paper shows experimental results on automatic formation of vehicle platoons on a Swedish highway. The influence of traffic density on the merge maneuver is illustrated. The results indicate that platoon coordination could be improved by support from appropriate traffic monitoring technologies.

1. Introduction

The need for mobility services is steadily growing and tightly linked to economic development. The transport system supports the local, regional, and global movement of people and goods, but the transportation sector is also responsible for a major part of the world's energy consumption and emissions [35]. In the European Union (EU) road transportation amounts for about a quarter of the total energy consumption and a sixth of all greenhouse gas emissions [13]. For another estimate of the importance of the road transport sector, recall that goods transport in the EU amounts to 3.5 trillion tonne-km per year and that 3 million people are employed in this sector, whereas people transport amounts to 6.5 trillion passenger-km and 2 million employees [13]. With increased specialization and globalization, freight transport is an ever more essential part of the manufacturing value chain. There is thus a strong social and economic motivation for developing a more sustainable and fuel-efficient freight transportation sector.

A rapid technical development has enabled self-driving vehicles, fuel-optimized cruise-controllers, and cooperative driving capabilities. We are on the cusp of a new era with major advances being introduced into the market and society over the next couple of decades. For example, vehicular communications [40, 21] enable a large set of new applications, such as collision warning and avoidance [39], automated intersections [11], and vehicle platooning [24, 2]. Vehicular position and velocity data are readily available today [16]. For freight transportation, such data can be combined with advanced vehicle models to make decisions on fuel-optimal routes. Transport systems spanning over large geographic areas with real-time data gathering can be used for increased efficiency and flexibility in the planning of transport assignments.

The development of a new freight transport system architecture based on these emerging technologies poses several obstacles. One challenge is simply the overall scale of the system: in the EU there are about 2 million heavy trucks[1] [3], the motorway network is about 73 000 km [13], and there are many fleet owners, drivers, and customers involved. Another challenge is the legacy of the system, as only a small percentage of the vehicles is renewed every year and the road infrastructure sees few and often very costly updates. Over the last twenty years, several ambitious proposals on how to build automated highway systems have been presented [47, 37, 18, 43]. The focus

[1] A heavy truck has a maximum loaded weight of more than 16 tonnes and is mainly used for transportation over long distances.