Network Design for Autonomous and Connected Truck Platoons to Improve Energy and Pavement Sustainability

Ruifeng She and Yanfeng Ouyang
University of Illinois at Urbana-Champaign

Abstract

Recent development on autonomous and connected truck (ACT) technologies has provided freight industries with new operational options to improve fuel efficiency, throughput, safety and highway infrastructure durability. One novel application is truck platooning, where fleets of freight trucks form closely spaced and longitudinally aligned platoons to gain fuel efficiency from reduced air resistance. However, such a practice introduces more frequent and more concentrated loading on pavement infrastructures, which may accelerate pavement deterioration and jeopardize safety and service to all highway users. This paper proposes a network design model to balance the tradeoff between truck operations and pavement life-cycle costs by optimally (i) design a network of special truck platoon lanes in a highway network, (ii) pooling and routing of ACT traffic from multiple origins and destinations to utilize these special lanes, and (iii) configure truck platoons within these lanes optimally for minimum energy consumption and pavement damage. The model is formulated as an integrated bi-level optimization problem, where the upper level makes decisions on converting highway lanes into platoon ones as well as setting fees for usage, while the lower level decisions are made by independent shippers regarding the choice of routes, use of special platoon lanes vs. regular lanes, steady-state fleet sizes that are adequate to form platoons, and detailed platooning configuration (e.g., lateral displacements and vehicle separations) on each link. Link cost functions for platoon lanes are derived based on mechanistic-empirical pavement design models as well as state-of-art pavement rehabilitation models. The proposed model is solved by customized network equilibrium and network design algorithms. Numerical examples are used to demonstrate the performance of the proposed model framework in optimizing the platoon lane network design over the Illinois highway system. The freight traffic is shown to be efficiently channelized on a subset of arteries where platooning is enabled and, by setting usage fees to subsidize pavement rehabilitation, traffic equilibrium is achieved on each of these links.