TOWARDS AN EFFICIENT AND SECURE RIDE-HAILING SERVICE

by

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ABSTRACT

Ride-hailing is the frontier of transportation innovations and has become an essential component of urban mobility. Addressing the efficiency of service operations and associated challenges has significant implications for the future of transportation systems.

In this dissertation, we develop a series of approaches and tools to enhance the efficiency of ride-hailing operations, validate operational controls in realistic scenarios, and assess the associated risks. Through extensive numerical experiments, we demonstrate the efficacy of our methods.

In Chapters 2 to 4, we develop three complementary control algorithms aimed at improving ride-hailing service efficiency:

- Chapter 2 focuses on proactive vehicle repositioning using a supervised learning model to recommend optimal pickup locations for vacant vehicles. The numerical experiments suggest this strategy can reduce empty vehicle mileage and also balancing driver income and vehicle utilization.

- Chapter 3 presents a hub-based ride-sharing algorithm that features an efficient data structure for querying feasible vehicle schedules and employs model predictive control to account for uncertainties in future demand and supply. This approach significantly outperforms baselines that do not account for future supply and demand or rely on point predictions.

- Chapter 4 addresses dynamic pricing in ride-hailing systems. We contribute to a rigorous definition of the problem and a reinforcement learning-based method to generate deterministic pricing policies. The numerical results suggest our approach can achieve near-optimal performance in promoting service income by effectively reducing empty vehicle mileage.

Chapter 5 introduces METS-R SIM, an agent-based simulator that combines detailed microscopic traffic simulation models with dynamic demand-supply matching. We validate METS-R SIM against actual ride-hailing data, demonstrating its ability to accurately re-

produce travel time and distance profiles and provide valuable insights for improving supply design and control strategies.

Finally, Chapter 6 explores the security challenges in autonomous mobility-on-demand (AMoD) systems. We develop a threat model to assess risks in the passenger-vehicle matching mechanism. Our experiments reveal that optimization-based attacks can significantly degrade service quality and increase traffic congestion, highlighting the need for extensive security analyses in autonomous ride-hailing operations.

Together, these contribute to a complete framework for improving ride-hailing systems with sophisticated operational algorithms, high-fidelity validation, and comprehensive risk assessments, paving the path toward a more efficient and secure ride-hailing service.