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Ensuring the robustness of link flow observation systems in sensor failure events

Dr. NING Zhu
College of Management and Economics, Tianjin University

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Abstract
Network link flow data are an intuitive information for monitoring the traffic condition of the entire network, and can be used to enhance traffic management and control. Link flow observation systems are typically designed using flow conservation equations to obtain the information of flow on unobserved links by inference. The occurrence of sensor failures in such systems may lead to flow information loss on both observed and inferred links. Most studies on this issue have considered sensor deployment and failure evaluation as separate processes. In contrast, in this study, both processes are integrated to establish a link flow observation system that withstands sensor failures. First, we propose a novel model to solve the sensor location problem for full link flow observability. The proposed model is then modified to evaluate the link flow information loss in sensor failure event, and incorporated into a distributionally robust optimization (DRO) model for the sensor location problem concerned. The DRO model minimizes the worst-case expected information loss of the system during the planning horizon with different types of sensors. Moreover, we extend the DRO model to a target-based version, into which a convex risk measure named Observation fulfillment risk index is introduced to evaluate the risk of failing to meet the predetermined observation target for any sensor installation schemes. The devised models can be directly solved by commercial solvers for networks like Nguyen-Dupuis, and a matheuristic genetic algorithm is designed for large-scale example networks. Numerical experiments are performed for networks with different sizes. The DRO model generates robust sensor location schemes with worst-case performances that are superior to those achieved using benchmark methods, such as stochastic programming. The use of the Observation fulfillment risk index enhances the system stability and target fulfillment level and decreases the standard deviation of the link flow information loss. We also make use of numerical experiments to derive some insightful conclusions on installation budget, coverage ratio, failure risks, etc..

About the Speaker
Dr. NING Zhu is a Professor in the College of Management and Economics at Tianjin University. His research interests encompass transportation and logistics system modeling, operation, and optimization. He focuses on various research problems including traffic sensor locations, transit system modeling (including bus stop modeling and related topics), vehicle routing problems, bike sharing system operations, disaster operations and management. Ning Zhu employs technical tools such as mixed-integer programming, stochastic programming, robust optimization, and stochastic processes to tackle these problems. He has published more than 40 academic papers in international journals such as Transportation Science, Transportation Research Part B/C/E, INFORMS Journal on Computing, Manufacturing & Service Operations Management and the European Journal of Operational Research. Additionally, he is the Principal Investigator for four national natural science foundation projects, including one National Science Fund for Excellent Young Scholars.

- ALL ARE WELCOME -