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Title:
Network Monitoring under Strategic Disruptions

Abstract:
This work considers a resource allocation problem for monitoring infrastructure networks facing strategic disruptions. The network operator is interested in determining the minimum number of sensors and a sensing strategy, to ensure a desired detection performance against simultaneous failures induced by a resource-constrained attacker. To address this problem, we formulate a mathematical program with constraints involving the mixed strategy Nash equilibria of an operator-attacker game. The set of player strategies in this game are determined by the network structure and players' resources, and grow combinatorially with the network size. Thus, well-known algorithms for computing equilibria in strategic games cannot be used to evaluate the constraints in our problem. We present a solution approach based on two combinatorial optimization problems, formulated as minimum set cover and maximum set packing problems. By using a combination of game-theoretic and combinatorial arguments, we show that the resulting solution has guarantees on the detection performance and admits a small optimality gap in practical settings. Importantly, this approach is scalable to large-scale networks. We also identify a sufficient condition on the network structure for this solution to be optimal. Finally, we demonstrate the scalability and optimality guarantee of our approach using a set of benchmark water networks.