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Distributed Monitoring Problem

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Abstract

The distributed monitoring problem refers to the placement and configuration of passive monitoring points to jointly realize a task of monitoring traffic flows. Given a monitoring task, the objective consists in minimizing the total monitoring cost to realize this task. We formulate this problem as a mixed-integer program. This formulation can also be dualized to determine the gain obtained when varying the number of monitoring points (i.e., the installation cost) and the fraction of monitored traffic (i.e., the configuration cost). As traffic flows can follow different paths depending on the routing strategy, we compare the resulting cost and gain when they are routed along the min-cost path, the paths obtained by solving the min-cost multicommodity flow and the multicommodity capacity network design problem.

Keywords: mixed-integer programming, network monitoring, optimal placement.

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1 Introduction

The cooperative monitoring problem consists, given a network topology represented by the graph $G = (V, A)$ with vertex set V and arc set A, in determining a set of arcs $(i, j) \in A$ where to place a set of monitoring points together with their optimal configuration in order to cooperatively realize a joint task of monitoring traffic flows. Monitoring a total fraction k of the traffic flowing along a given path involves the cooperation between monitoring points since the traffic sampled at a given monitoring point is not sampled again at another point along the same path. The corresponding optimization problem consists, knowing the traffic demands, in minimizing the total monitoring cost such that a given traffic monitoring task can be jointly realized. The monitoring cost includes the cost associated to the installation of a monitoring point along arc (i, j) and the cost associated to its configuration. The latter translates the capacity required at each monitoring point proportionally to the fraction of traffic captured at that point.

As the monitoring cost depends on the spatial distribution and the temporal properties of the traffic flows established across the network, as determined by the routing strategy, the resulting optimization problem formulates as a mixed-integer non-linear program (MINLP) where the continuous monitoring fraction variables are multiplied by the continuous flow variables. The latter can be derived by resolving the min-cost flow (MCF), the min-cost multicommodity flow (MMCF) or the multicommodity capacitated network design (MCND) problem depending on the routing strategy adopted. The formulation can also be dualized to determine the monitoring utility gain obtained when varying the budget constraint imposed on the total monitoring cost. The corresponding optimization problem consists in maximizing the monitoring utility given budget constraints on the monitoring installation and configuration cost.

The proposed formulation differs from the one developed in [2] translating the task of monitoring imperceptibly a fraction k out of the total amount of traffic. In the present case, for each flow part of a (preselected) set of demands, a total fraction k of the traffic is sampled per-flow instead of assuming that some flows can remain unmonitored ($k = 0$) while for others the entire traffic can be sampled ($k = 1$). Following the formulation documented in [6], the sampling rate for each flow at each monitoring point can only be adjusted independently from the others along the same path. A global sampling strategy is adopted in [1] where the sampling rate is multiplied by the traffic load of each arc instead of individual flows as proposed in this paper.