



# Capacitated ring arborescence problems with profits

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## Abstract

In this work, we introduce profit-oriented capacitated ring arborescence problems and present exact and heuristic algorithms. These combinatorial network design problems ask for optimized bi-level networks taking into account arc costs and node profits. Solutions combine circuits on the inner level with arborescences on the outer level of the networks. We consider the prize-collecting, the budget-constrained and the target-profit models and develop corresponding exact branch-and-cut algorithms based on mixed-integer formulations and valid inequalities. Iterated local search heuristics based on the exploration of problem-specific neighborhoods are elaborated to strengthen the upper bounds. For a set of hard literature derived instances with up to 51 nodes, we provide computational results which give evidence for the efficiency of the proposed approaches. Furthermore, we extensively analyze the performance of our methods, the obtained solution networks and the impact of the cutting planes on the obtained lower bounds.

**Keywords** Network design · Ring arborescence problem · Vehicle routing problem · Orienteering problem · Prize-collecting Steiner tree problem · Mathematical programming

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