

# Exploring AI approaches to improve the resolution of unsplittable multicommodity flow problems in wireless networks

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The unsplittable multicommodity flow problem appears in various applications such as traffic optimization in telecommunication networks, transportation problems of robots and autonomous vehicles, and emerging smart city and smart mobility deployments. We focus on the problem of energy efficiency in wireless networks [3]. Given a bi-directed graph  $G = (V, E)$ , where  $V$  represents the set of nodes corresponding to wireless transmission devices and  $E$  denotes the set of transmission links that can be used to carry traffic, unsplittable traffic demands denoted by a set  $D$  of source-target node pairs  $(s, t)$ . We seek to find a unique routing path for each demand that minimizes the total energy cost under capacity and demand constraints. This problem generalizes the bin packing, partition or disjoint path problems, which are themselves NP-hard. To efficiently solve this NP-hard combinatorial problem, we consider different approaches and compare empirically their performances. The first approach is based on the polyhedral study of the problem [2]. In the literature, few studies have focused on the polyhedral structure of the unsplittable multicommodity flow problem. Indeed, most of the developed solution approaches are based on approximation algorithms. The cut and cover inequalities as well as the metric inequalities used in the literature do not represent the fact that only one path is assigned to each demand. We use the bin packing structure of the unsplittable multicommodity flow to develop new valid inequalities, that more efficiently express unsplittable routing constraints. We propose new classes of valid inequalities implemented in a branch-and-cut algorithm. However, the size of the instances solved by this algorithm remains limited. To improve the performance of our algorithms, we propose new approaches combining the efficiency of constraint programming and SAT solvers with combinatorial optimization methods. This approach takes advantage of the use of binary variables in our

models. The problem with Boolean decision variables can be solved efficiently with "modern" SAT solvers. In addition, the particular linear constraints allow the use of pseudo-Boolean solvers [1], which apply cut-plane based reasoning, known to be more powerful than SAT solvers. Finally, we propose a third approach based on constraint programming solvers. These solvers generalize SAT or pseudo-Boolean solvers by using a wide variety of constraints on binary variables. These solvers implement many efficient data structures that lead to high numerical performance on a wide variety of problems.

## References

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