Ph.D. in Information Technology:
TACCARI Final Dissertation

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Ph.D. presentation and discussion:

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Mixed-Integer Programming Models and Methods for Bilevel Fair Network Optimization and Energy Cogeneration Planning

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Abstract:

This thesis addresses two relevant mixed-integer optimization problems, with application in telecommunications and energy systems, using mathematical programming techniques. The first part focuses on a bilevel multi-commodity flow problem subject to max-min fair flow allocation, which arises in telecommunication networks with elastic demands. The problem is motivated by routing in internet protocol (IP) networks, where there are no prescribed demands to be satisfied, since the network provides a best-effort service. The network operator aims at maximizing a utility function (total throughput), by selecting the routing paths, while the bandwidth is allocated fairly by the distributed transport protocol. Accordingly, we define the maximum-throughput Unsplittable Flow Problem subject to Max-Min Fair flow allocation (UFP-MMF) as the bilevel problem where, at the upper level, the routing paths maximizing the total throughput are sought, while, at the lower level, the flow is allocated to each origin-destination pair maximizing a fairness measure. The bilevel problem can be cast as a single-level mixed-integer programming problem exploiting the concept of bottleneck arcs, but it remains very challenging. We develop two MIP-based approaches: a branch-and-cut algorithm based on an arc formulation, where subtour are prevented separating generalized cutset inequalities, and a branch-and-price algorithm based on a path formulation. We also propose an efficient local search heuristic that provides close-to-optimal solutions in a short computing time on a set of realistic instances. Finally, we discuss relaxations of UFP-MMF, involving alternative fairness criteria, that provide tight dual bounds. The second part of the thesis studies an operational planning problem arising in energy cogeneration systems with thermal storage. The goal is to determine the operational schedule of a set of (co)generation units (i.e., on/off status and production level), over a given time horizon, in order to minimize the operating costs while satisfying users demands. After a brief survey on previous and related work, we discuss mixed-integer programming formulations, focusing on some basic variants of the problem. For the variant with constant production upper and lower bounds, a polynomial dynamic programming algorithm is described. To account for uncertainties in the demand forecast, we propose a formulation based on gamma-robustness. Finally, we tackle some real-world instances of the problem, solved as a MINLP or as a MILP, exploiting a piecewise-linear approximation