A Topology Aggregation-based Approach for the Unsplittable Shortest Path Routing Problem

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1 Introduction

The Unsplittable Shortest Path Routing problem (USPR) is one of the optimization problems that has been well studied in the field of traffic engineering for IP networks due to its importance for improving the Quality of Service (QoS) of IGP networks. Given a directed graph G representing the IP network and a set of commodities K depicting the demands to be sent between its nodes, the USPR problem consists on identifying a set of routing paths and the associated administrative weights such that each commodity is routed along the unique shortest path between its origin and its destination following these weights. The USPR problem is proven to be NP-hard and thus, many studies have used meta-heuristics to solve it.

2 Proposal

In this work, we propose a topology aggregation-based (TA) approach to solve the USPR problem, which consists on efficiently aggregating the network's graph to make it more scalable before solving it using the MILP formulation presented in [1] with the objective of minimizing the maximum load. An overview of the approach proposed is depicted in Figure 1. The starting point is the network's topology to be studied, which is represented by the graph G and a traffic matrix K containing the set of demands to be routed between nodes (for sake of simplicity, G in Figure 1 is representing a bi-directed graph but the upload and download links between nodes are separated and can have different weights). The first step consists of using the proposed aggregation method GNC (Girvan-Newman/Clique) to select the sub-graphs to be aggregated. This process is based on the Girvan-Newman algorithm ([2]) for communities detection within graphs and combined with the graph's notion of clique. Then, a new graph is

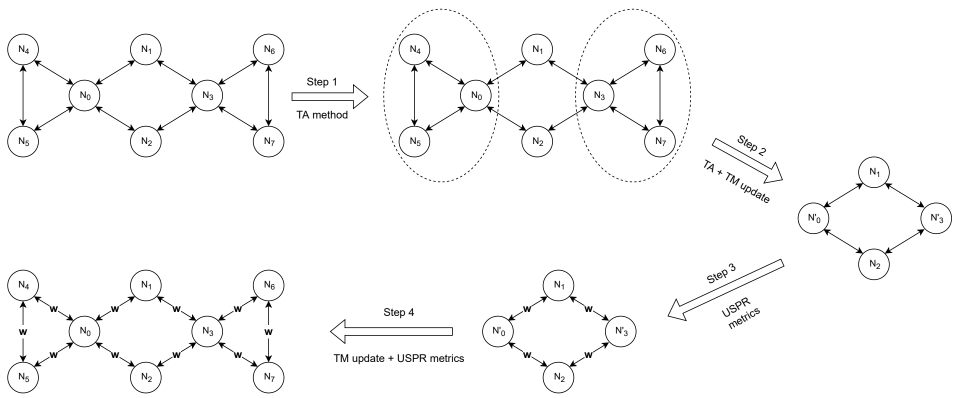

FIG. 1 – Topology aggregation method for USPR.

generated according to the aggregations created along with a new traffic matrix (TM) where commodities will also be aggregated following the considered aggregations. The new traffic matrix represents commodities aggregated to fit with nodes of the aggregated graph. The next step now consists on applying the USPR solver on the newly generated graph to compute the set of different weights to be assigned to the links. In the next and final step, we adapt the initial TM (by keeping in each commodity only the sub-flows that have not been treated yet) in order to be able to apply the USPR solver on the aggregated sub-graphs. Now, we have a full configuration of weights on all the links.

3 Results

Topology	InvCap	NRPA	GNC	Time GNC	Time NRPA	Time OPT
Abilene	48.12%	0%	0%	20 sec	10 min	50 sec
Atlanta	54.58%	5.04%	36.52% (0%)	2 min	10 min	4 min
Newyork	68.88%	44.4%	28.8% (2.22%)	2 min	30 min	> 4320 min
France	70.92%	19.50%	60% (15.7%)	72 sec	30 min	> 4320 min
Nobel-us	53.51%	2.06%	0%	6 min	10 min	58 min
Nobel-ger	43.15%	13.69%	9% (6.75%)	1 min	10 min	122 min
Nobel-eu	24.74%	0.28%	4.12% (1.31%)	8 min	30 min	1250 min

TAB. 1 – Comparison results.

To evaluate our proposal, we compare it to InvCap (links weights are inversely proportional to the capacities) and NRPA [3]. We report in Table 1 the maximum load gap relative to the optimal value (using the MILP formulation of [1]) and the execution time of each method (InvCap results are obtained instantly). The experiments were done on some networks with various sizes and characteristics that were taken from SNDlib. We can see from the reported results the impact of topology aggregation on reducing the execution time. In terms of maximum load gap, the results vary depending on the tested network topology and its characteristics but in general, we obtain good results (the second values shown in GNC column represent the results obtained by using a local search method combined with the GNC algorithm).

4 Conclusions and perspectives

To solve the USPR problem, we propose a novel approach based on the topology aggregation paradigm. The proposal consists on a TA-based methodology applicable to our use case in which an algorithm called GNC based on the Girvan-Newman community detection algorithm is used. The conducted experiments to evaluate GNC and compare it to other methods have shown the potential of using a TA-based method to solve the USPR problem. We intend in the future to improve our aggregation algorithm and conduct more extensive experiments to validate our work by testing other network configurations with challenging settings and considering the delay-constrained version of USPR.

Références

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