Enabling E-Mobility: Facility Location for Battery Loading Stations

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WHERE TO PLACE LOADING STATIONS FOR ELECTRIC VEHICLES IN ORDER TO ...

... GET ANYWHERE

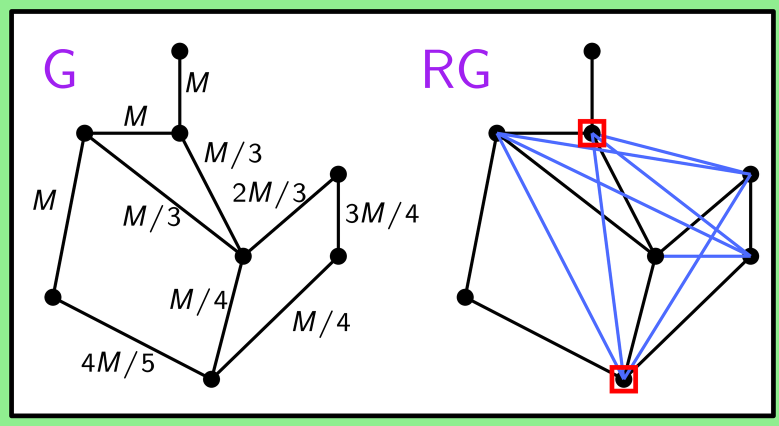
GIVEN graph $G(V, E)$, battery capacity $M \in \mathbb{R}^+$

GOAL Place as few loading stations as possible such that one can reach all destinations from any source with an electric vehicle (EV) without running out of energy. **(EV-Reachability Cover = ERC)**.

BASIC IDEA Create reachability graph $RG(V, E^+)$ with $(v, w) \in E^+$ if w can be reached from v.
$\Rightarrow$ ERC can be reduced to find a Strongly Connected Dominating Set in RG.

TAKE AWAY

ERC can be $c \cdot \ln n$ approximated with $c = 3$ but is inapproximable for $c < 1$.



... GET ANYWHERE AND BACK

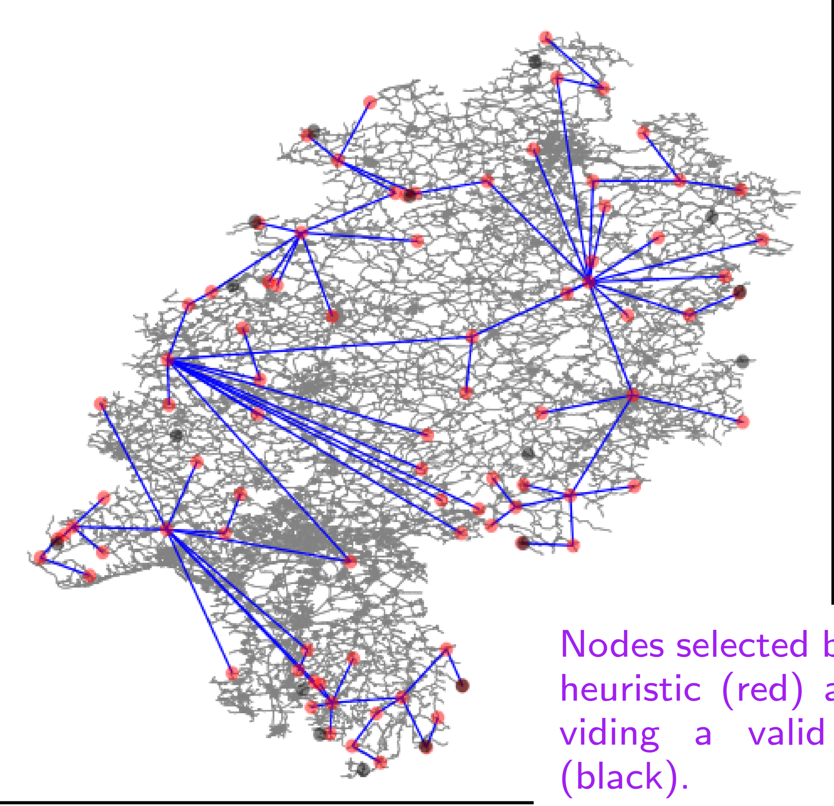
GOAL Place as few loading stations as possible such that one can reach all possible destinations from any source and return to the source without running out of energy **(EV-Connectivity Cover = ECC)**.

BASIC IDEA Create first ERC solution, then lift it to ECC by selecting additional loading stations. This selection process is closely related to the Set Cover by Pairs problem.

TAKE AWAY

ECC can be approximated within $\mathcal{O}(\sqrt{n \log n})$ and has a worse inapproximablity bound than ERC.

HEURISTICS AND INSTANCE BASED LOWER BOUNDS



Nodes selected by the k-Greedy heuristic (red) and nodes providing a valid lower bound (black).

Theoretical results are rather discouraging: no constant approximation possible in polytime!

BUT Simple heuristics achieve good solutions in practice (provable via instance based lower bounds).

k-Greedy Heuristic

- select k candidate nodes u.a.r., determine for each one in the role of a loading station the number of nodes that would be newly covered
- choose the candidate with the highest impact and add it to the solution
- remove all nodes from the search space, which are covered
- select a new candidate node u.a.r to refill the candidate list

&

Lower Bound
Compute maximal set of nodes which pairwise can not be coverd by the same loading station.

avg. cruising range	lower bound	ERC	ECC
75 km	105	339	812
100 km	49	147	379
125 km	37	103	268
150 km	22	61	187
175 km	14	46	138

Experimental results on the road network of Germany. ACR denotes the average cruising range of the electric vehicle. The approximation ratio of our approach ranges between 2.7 to 3.3 for ERC and 7.2 to 9.8 for ECC.