Enabling E-Mobility: Facility Location for Battery Loading Stations

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 $O(\sqrt{n \ln n})$ and has a worse inapproximability bound than ERC.

HEURISTICS AND INSTANCE BASED LOWER BOUNDS

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 covered by the same loading station.

<table>
<thead>
<tr>
<th>avg. cruising range</th>
<th>lower bound</th>
<th>ERC</th>
<th>ECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 km</td>
<td>105</td>
<td>339</td>
<td>812</td>
</tr>
<tr>
<td>100 km</td>
<td>49</td>
<td>147</td>
<td>379</td>
</tr>
<tr>
<td>125 km</td>
<td>37</td>
<td>103</td>
<td>268</td>
</tr>
<tr>
<td>150 km</td>
<td>22</td>
<td>61</td>
<td>187</td>
</tr>
<tr>
<td>175 km</td>
<td>14</td>
<td>46</td>
<td>138</td>
</tr>
</tbody>
</table>

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.