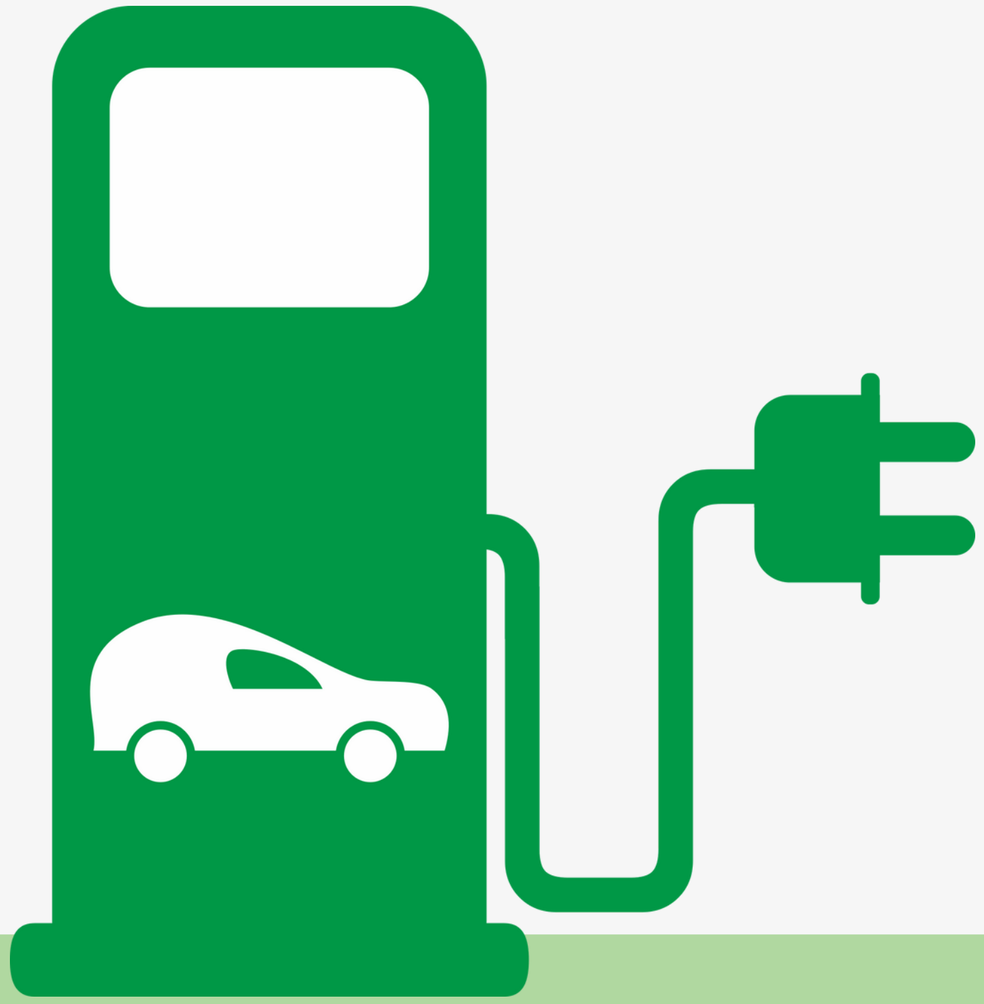
Qiskit Global Hackathon
2021

QAOA for smart charging of electric vehicles

Approaching industrial NP-hard problems



Our Motivation:

to work for a better future

Climate change is one of the greatest challenges of our time. In order to still reach the 1.5° target, all scientists must join forces and ask themselves how they can make a contribution with their research.

That is what we have done. In order to slow down climate change, electric cars will gain in importance in the future.

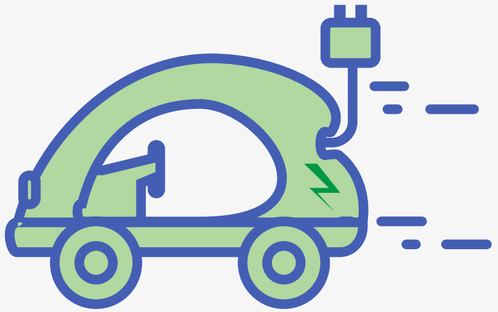
What is Smart Charging?

bidirectional charging

Vehicle to grid

batteries as energy storage and power supply

personalized charging



better time management

improve the flexibility of the electric system

reducing high-peaks

providing electicity if demand is high

2 Problems connected with Smart Charging

Minimization of Total Weighted Load Completion Time

Optimal Scheduling of Load Time Intervals within Groups

Minimization of Total Weighted Load Completion Time

J = {1, . . . , n} : charging jobs

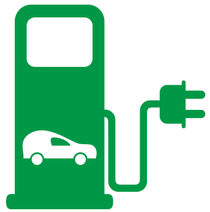
n : electr. vehicles

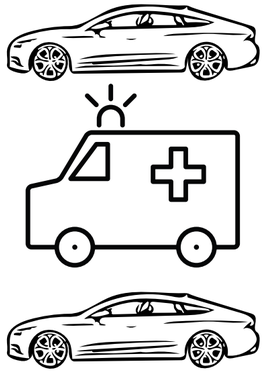
T = {t1, . . . , tn} : charging duration

I = {1, . . . , k} : set of k charging points

wj > 0 : weight, measuring the importance

Cj : completion time



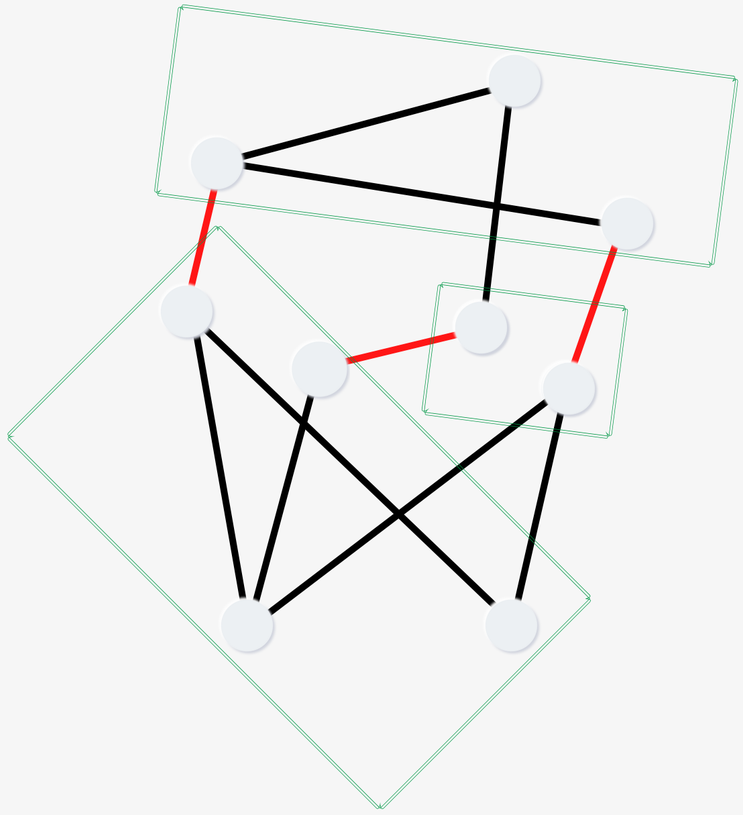


Task: minimizing the weighted total time of completion of the charges:

$$\sum_{j \in J} w_j C_j$$

This problem is a Max-k-Cut problem

- Each *node* is a job with weight w and takes time t to complete, each edge between nodes i and j is min{w_i*t_j, w_j*t_i}
- w_i*t_j is the cost, which incures by putting job j before i (it's proportional to the importance of job i and to the time lost for i)
- If an edge is short, it has a huge cost; none of the node jobs should wait for the other -> vehicles should be sent to different charging ports
- Applying Max-k-Cut gives *k connected subgraphs* by getting rid of *short edges*
- The nodes of each subgraph represents vehicles that can be in the same queue



Our assumptions

In order to design a simple environment for solving the problems we make some restrictions to reality.

- load station is made up of several charging points
- each load station can charge a single car at a given time step
- charging points supply same power
- charging time is independent of charging point
- no consideration of job characteristics or global constraints
- load tasks can not be interrupted

Implementation

Data Creation: We used networkx to design a graph. We created random charging times and weights for n cars. After that we assigned cost values to the connections between two cars.

Max-k-Cut Implementation: blabla

Benchmarking: blabla

Results

Graph

- ..
- ...
- ...
- ...
- ....

Optimal Scheduling of Load Time Intervals within Groups

Delete if we do not get here

I = {(s_1, e_1) (s_nk, e_nk)}:
set of intervals (load job start- and end- date)

n : number of groups

k : number of tasks

Given: a set of load tasks represented as intervals on a timeline

Tasks:

1. maximizing the number of non-overlapping tasks
   a. at most one load in each group
2. minimize the completion time of the selected loads
   a. no group should be over-represented

optimal solution: Maximum Independent Set (MIS)

Summary: What we have done

Implementation 1

Implementing an algorithm minimizing the total weighted load completion time

Benchmarking

dddasdadsa

Implementation 2

Implementing an algorithm for the optimal scheduling of load time intervals within groups

Research

Understanding the field of smart charging

adjust in the end

Next steps

Improving

A next step would be to change the assumptions in order to make it more realistic. External factors, like the status of the grid should be caputured. Moreover, it should be possible to interrupt a load task.

Scaling

To perform better than existing classical solutions, it is necessary that quantum computers will scale up.
Moreover, we need to go into an iterative circle: By benchmarking our algorithm against other existing models, we can iterativly improve and verify our results.

Developing

The long-term goal would be to design an app, where electric car users can enter the time, when they need their car again and for approximatly how many km. The app then calulates the best order to charge the cars by takng also external factors into account.

Our Team

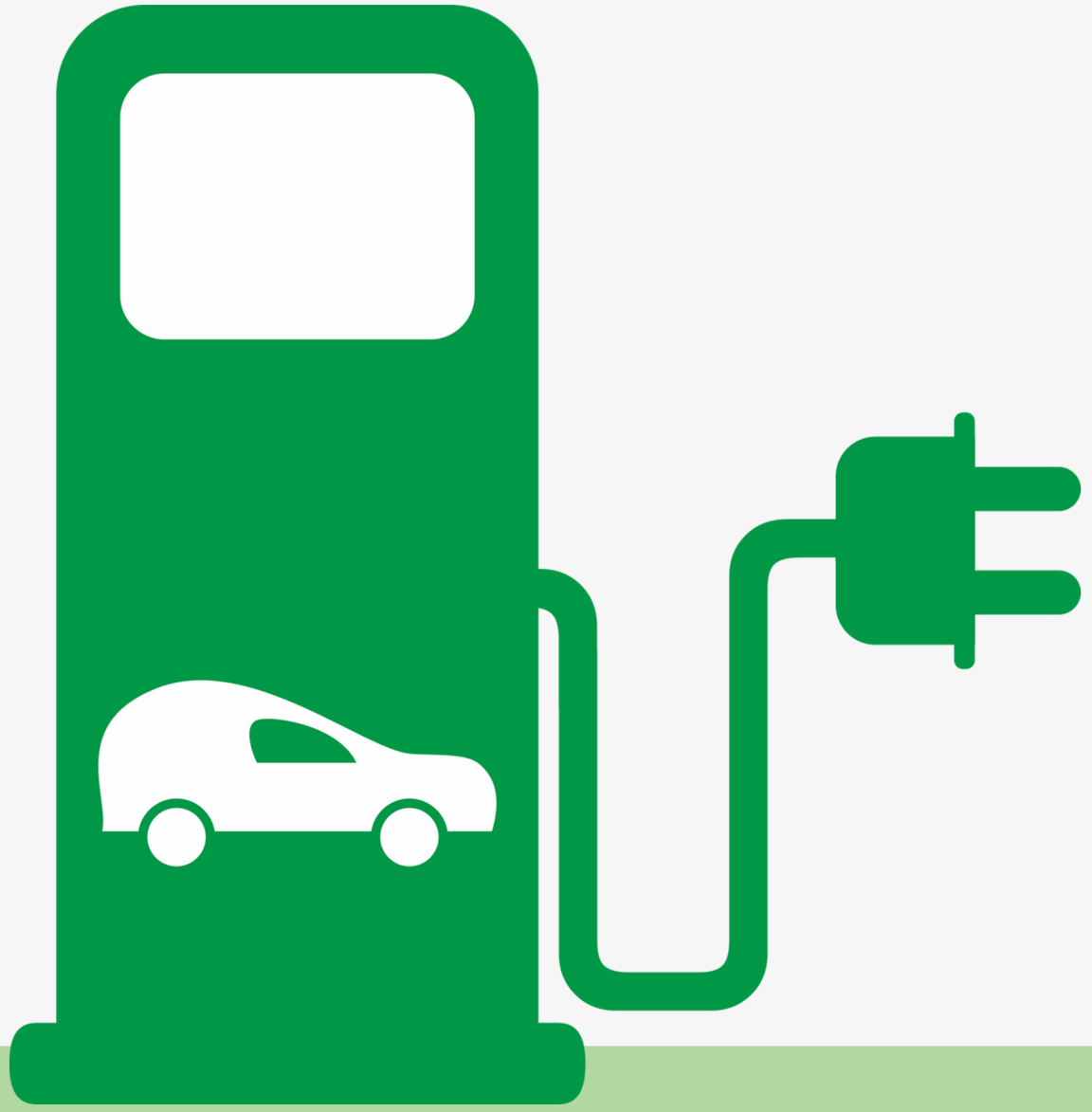
Kevin Shen
Quantum Science & Technology M.Sc.
Technical University of Munich

Catharina Broocks
Quantum Science & Technology M.Sc.
Technical University of Munich

Franziska Wilfinger
Quantum Science & Technology M.Sc.
Technical University of Munich

Jakob Pforr
Quantum Science & Technology M.Sc.
Technical University of Munich

JezerJojo
BSMS
IISER Pune



Thank you!

Resources

- https://github.com/fjelljenta/Smart-Charging
- https://arxiv.org/pdf/2012.14859.pdf
- https://www.osti.gov/servlets/purl/1756438