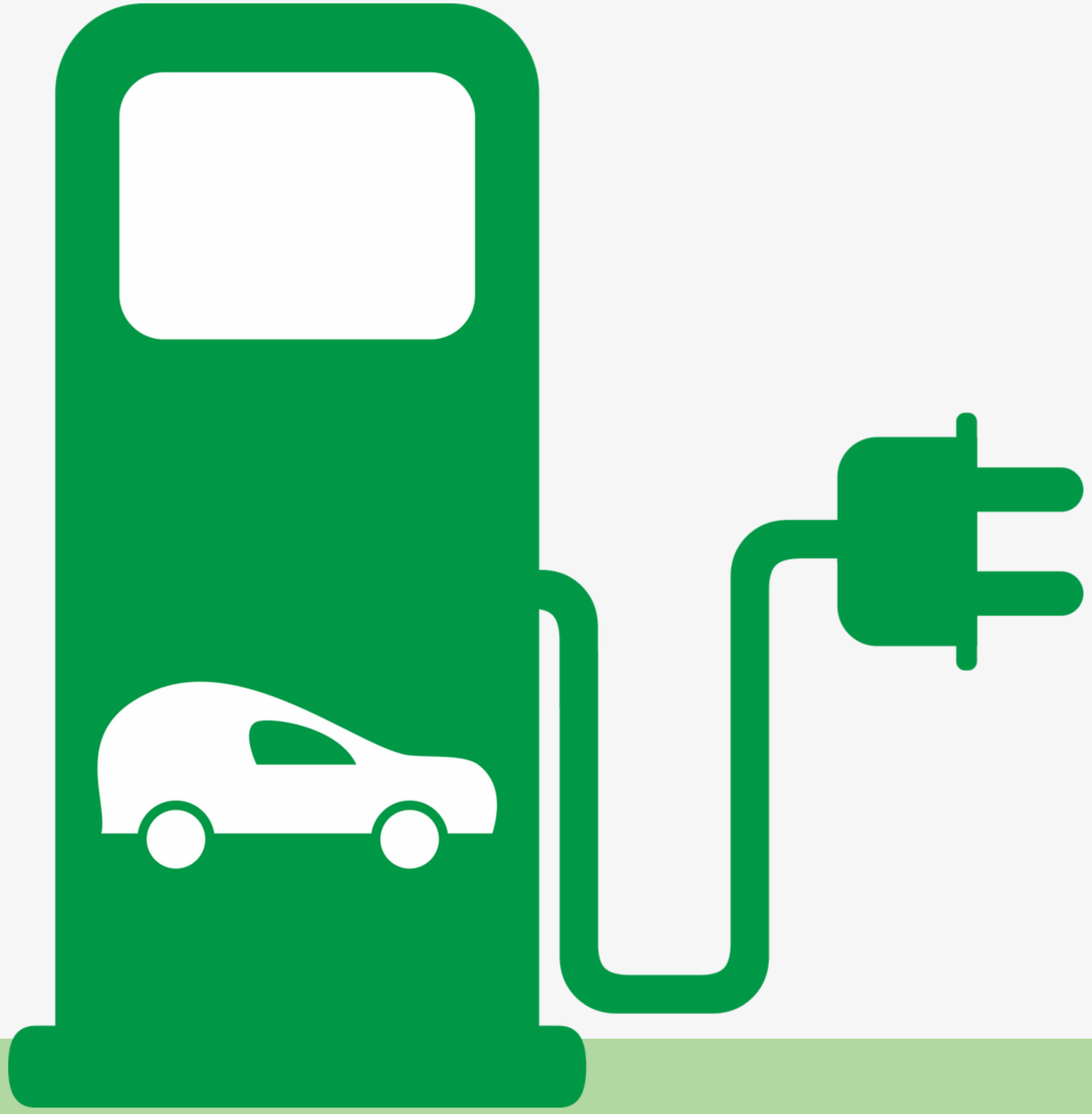
Qiskit Global Hackathon
2021



QAOA for smart charging of electric vehicles

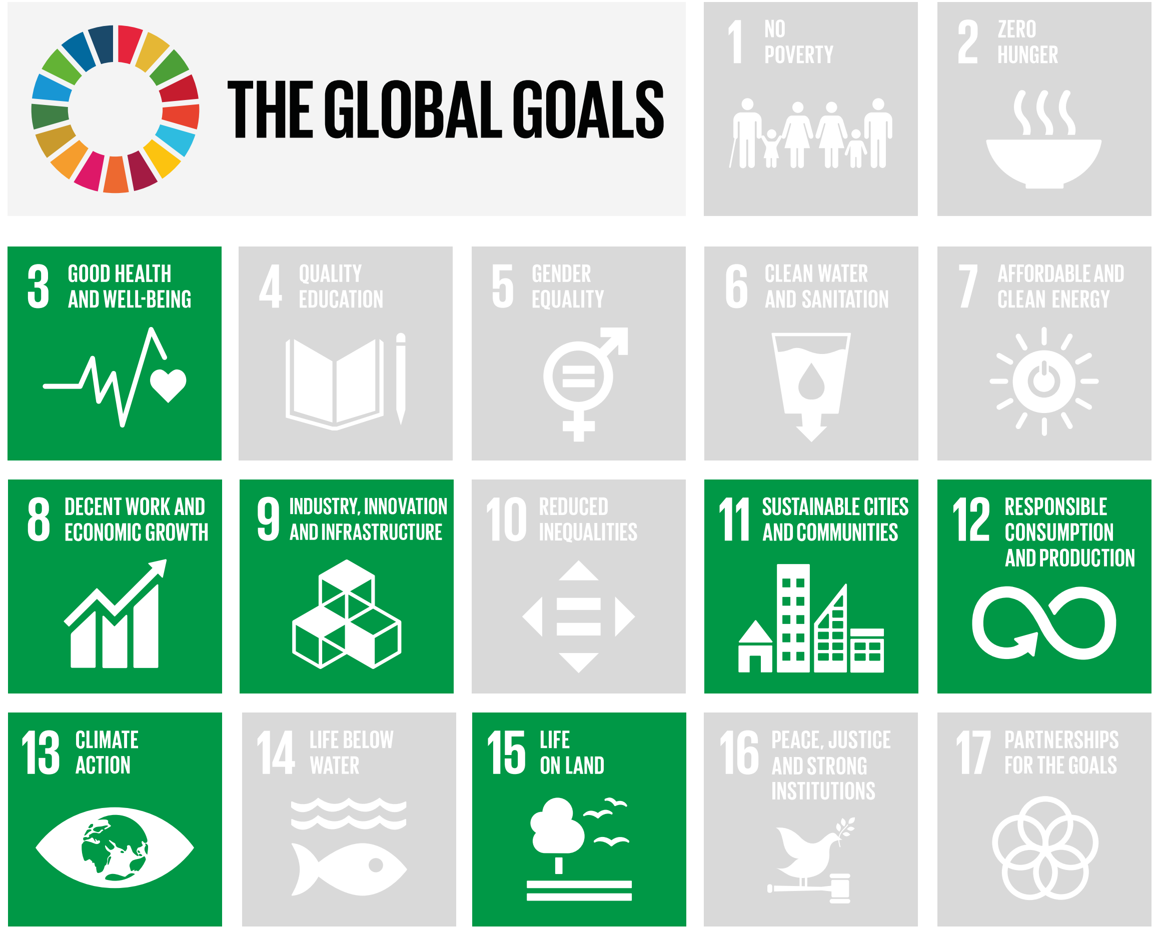
Approaching industrial NP-hard problems

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.


THE GLOBAL GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

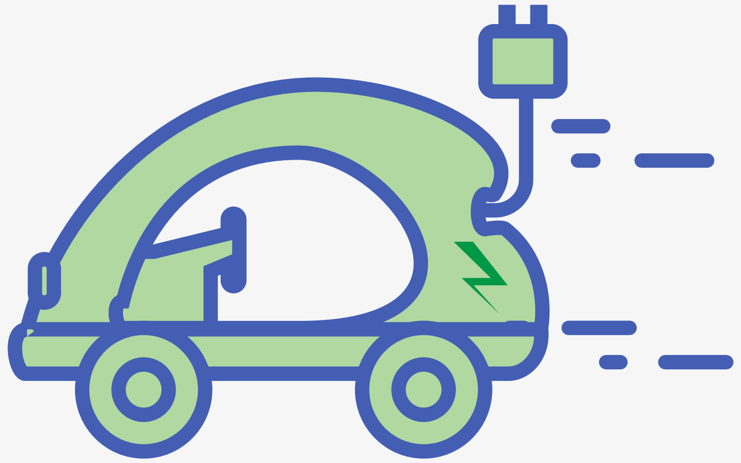
What is Smart Charging?

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

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

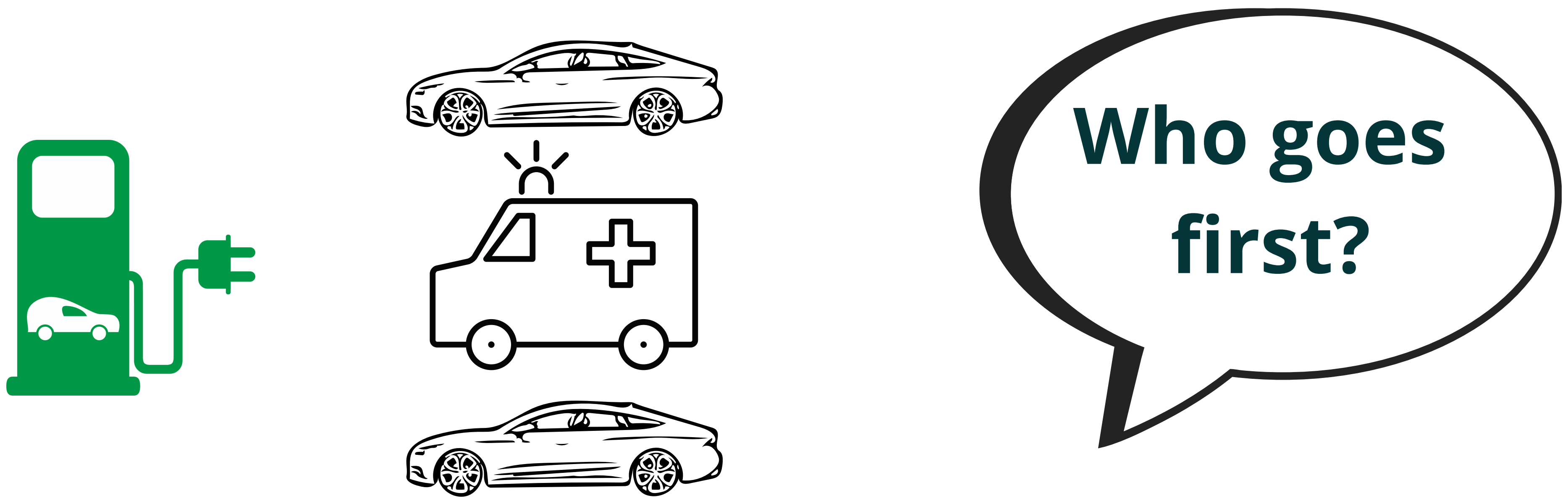
○ charging time is independent of charging point

○ no consideration of job characteristics or global constraints

○ load tasks can not be interrupted

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

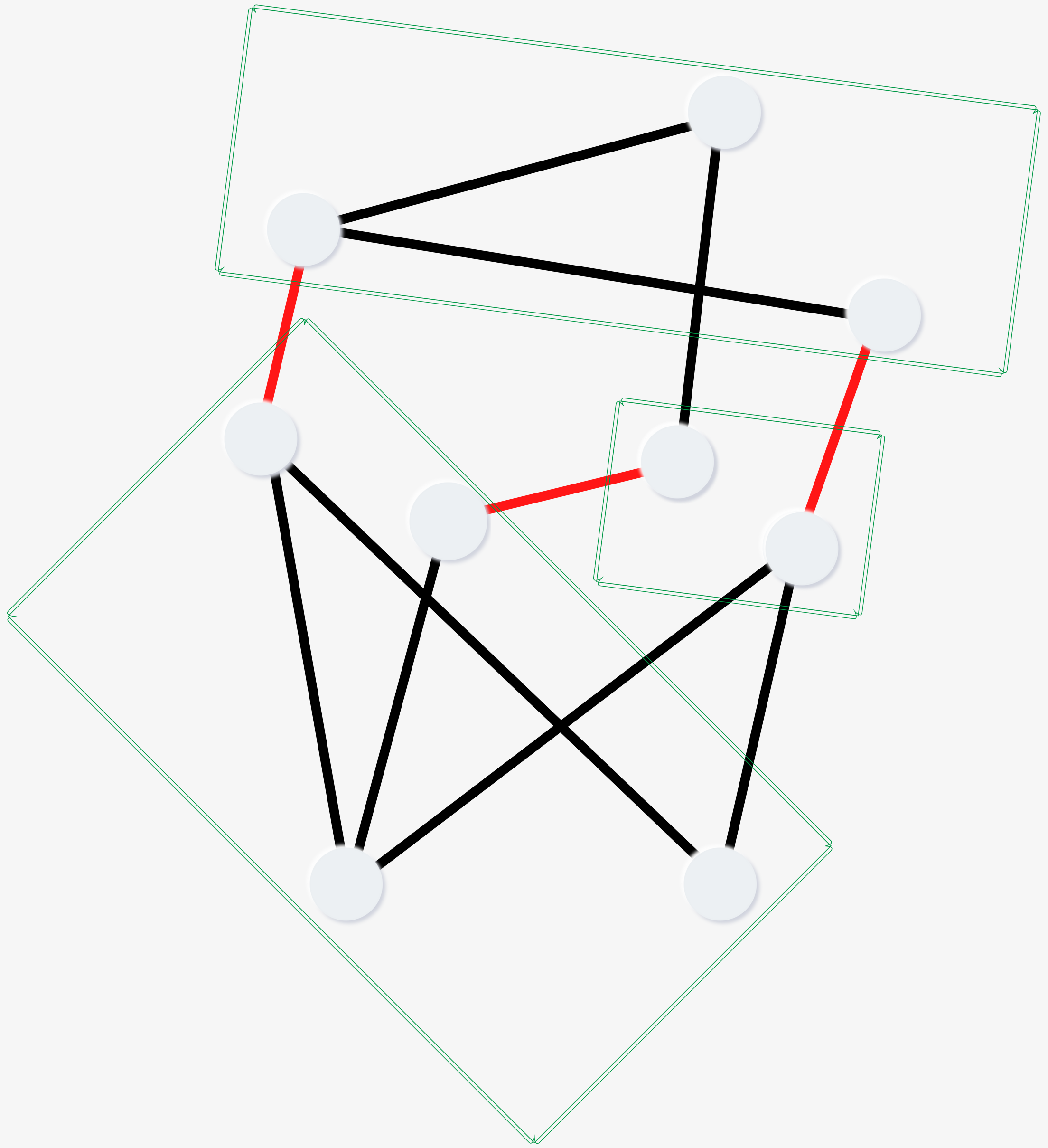


Task: minimizing the weighted total time of completion of the charges:

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

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



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

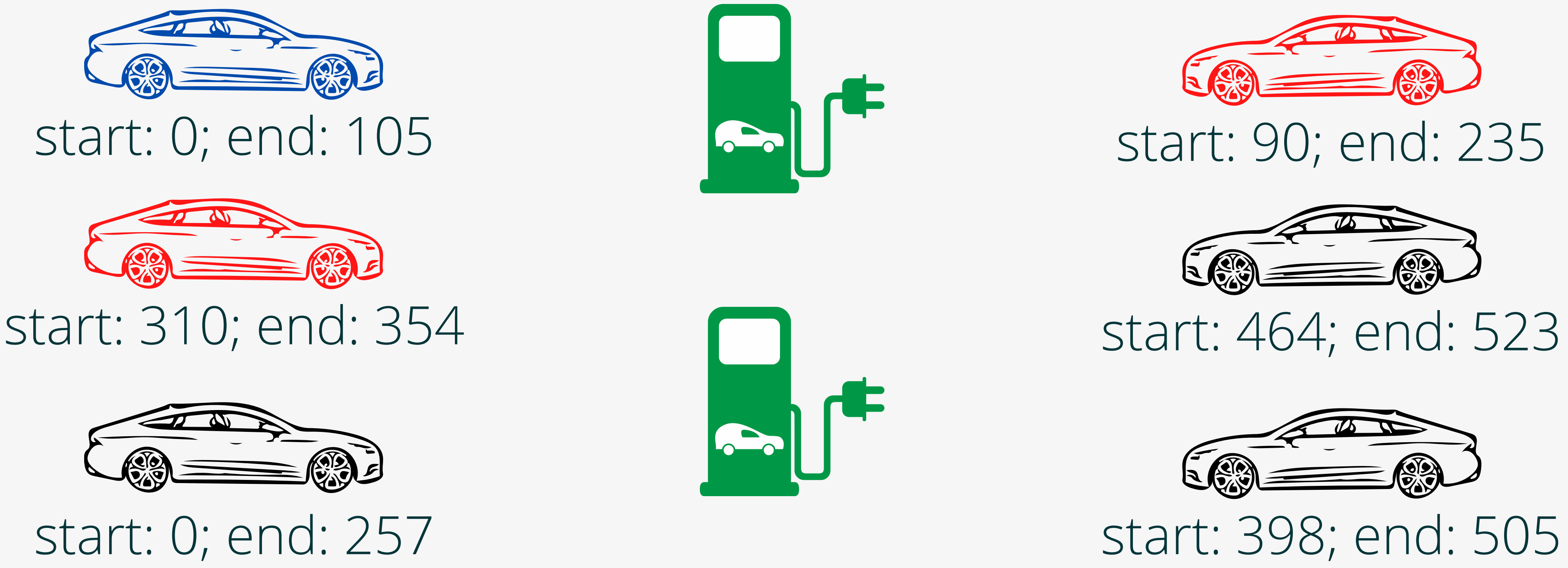
- ○ ..
- ○ ...
- ○ ...
- ○ ...
- ○ ....

Optimal Scheduling of Load Time Intervals within Groups

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



start: 0; end: 105

start: 310; end: 354

start: 0; end: 257

start: 90; end: 235

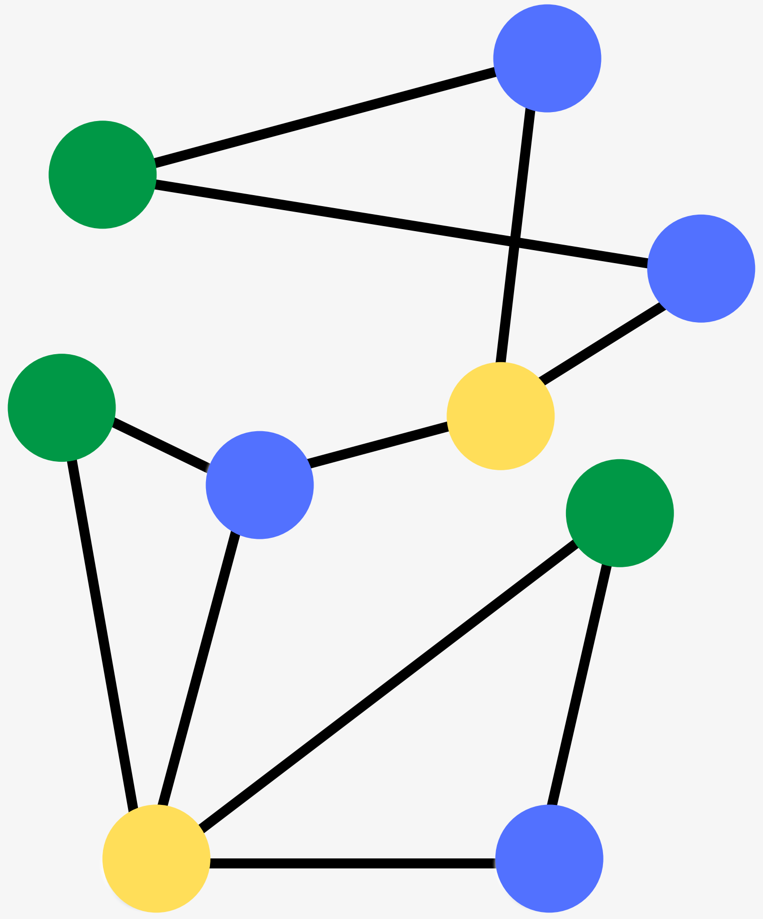
start: 464; end: 523

start: 398; end: 505

Tasks: Which cars should share a charging point, so that no group (colour) is overpresented (max. one load in each group simultaneously) and that the number of non-overlapping tasks is maximal?

The optimal solution is a Maximum Independent Set

- A Maximum Independent Set (MIS) is an independent subset, which is not part of an other subset.
- Each node represents a car, so each node has three attributes: group, start time and end time.
- There is a connection between two nodes if 1) the two nodes are in the same group or 2) the charging intervals are overlapping or 3) both is true.
- The goal is now to find a maximal subset of not connected nodes. The number of subsets is equal to the number of charging points.



Implementation

Data Creation: We used networkx to design a graph. For k cars we created random charging intervals and assign them to n groups. After that we connected cars within the same group and/or within the same time interval.

MIS Implementation: blabla

Benchmarking: blabla

Results

Graph

○ ..

○ ...

○ ...

○ ...

○ ....

Summary: What we have done

Research

Understanding the field of smart charging.

Implementation 1

Implementing an algorithm minimizing the total weighted load completion time & a benchmarking.

Implementation 2

Implementing an algorithm for the optimal scheduling of load time intervals within groups & a benchmarking.

Visual Simulation

Creating a Django web app with a visual simulation of what our code does.

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 algorithms 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 taking also external factors into account.

Our Team

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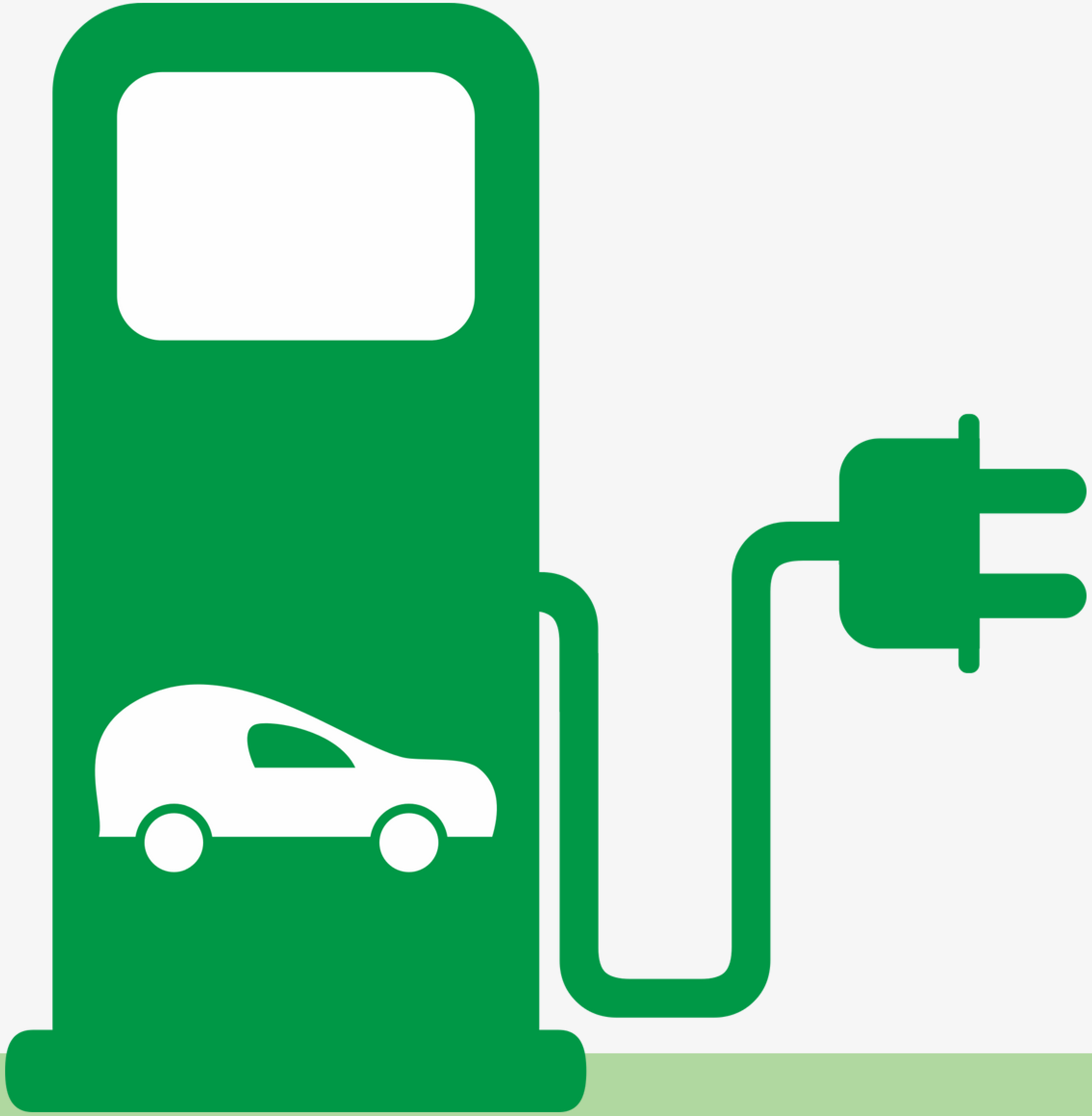

Thank you!

Resources

- https://github.com/fjelljenta/Smart-Charging
- https://arxiv.org/pdf/2012.14859.pdf
- https://www.osti.gov/servlets/purl/1756438
- https://qiskit.org/documentation/tutorials/optimization/6_examples_max_cut_and_tsp.html
- https://qiskit.org/textbook/ch-applications/qaoa.html