

# Qommunity: a library for community detection using quantum and classical methods

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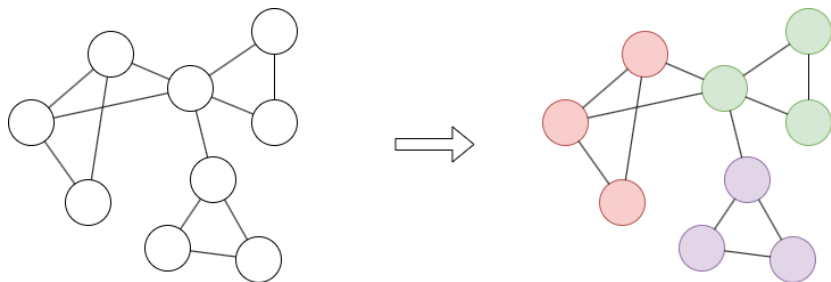
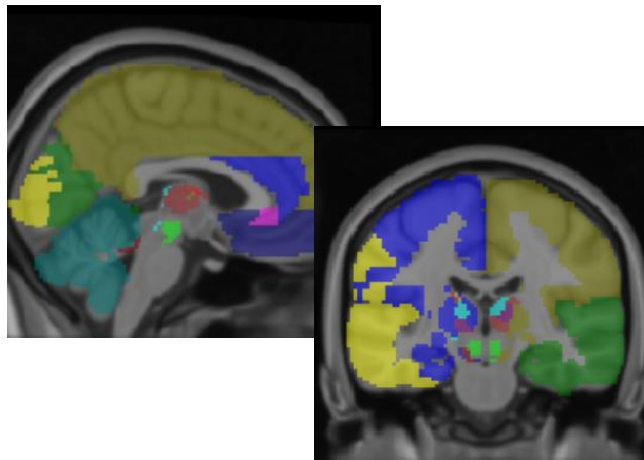
<sup>3</sup> Sano Centre for Computational Medicine



# Our motivation

The goal is to discover new functional areas of the brain and diagnose neurological diseases.

We want to achieve this by using quantum methods, which has not been used for this purpose so far



We are able to do this when we present the brain in the form of a graph and look for communities in it

# Key objectives

- **Development of a tool to facilitate experiments on graphs** - both quantum, hybrid and classical methods
- **Developing an algorithm for hierarchical partitioning** - the quantum methods we use work on binary variables, so we need to find a way to partition the graph into more than two communities
- **Converting the problem** - Converting the brain network to a community detection problem expressed as various models, including QUBO - Quadratic Unconstrained Binary Optimization

# Solution concept

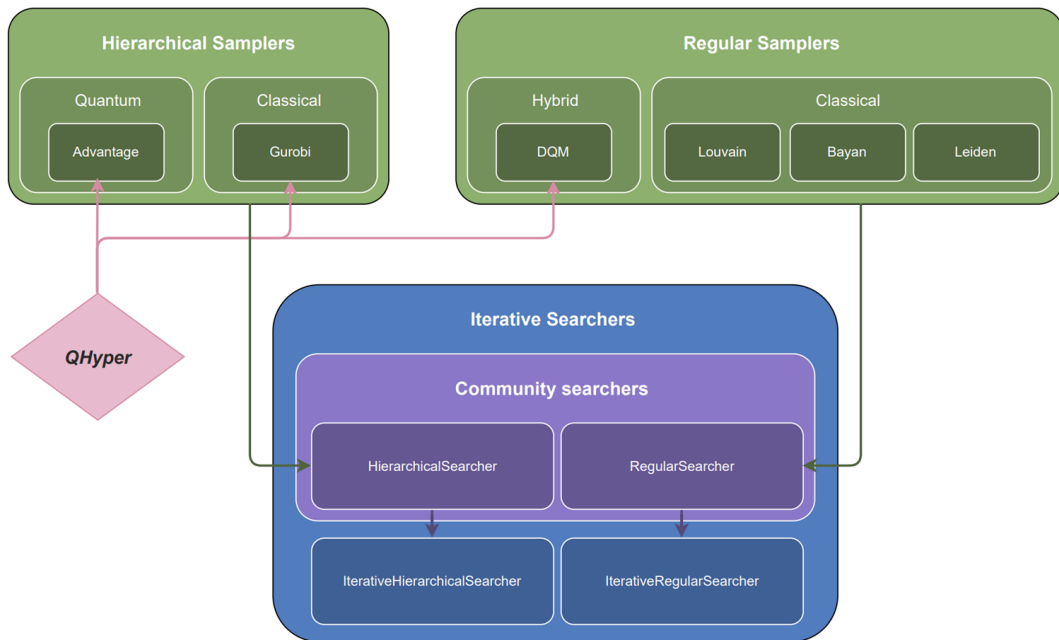
That is, what actions we have taken to achieve the goals:

- **Development of a community detection library - Qommunity**
- **Expansion of the current library, QHyper, to include a community detection problem**
- **Integration with D-Wave solvers**

# Qommunity Library

**Qommunity** is a library created for detecting communities in graphs, integrating classical, quantum and hybrid methods.

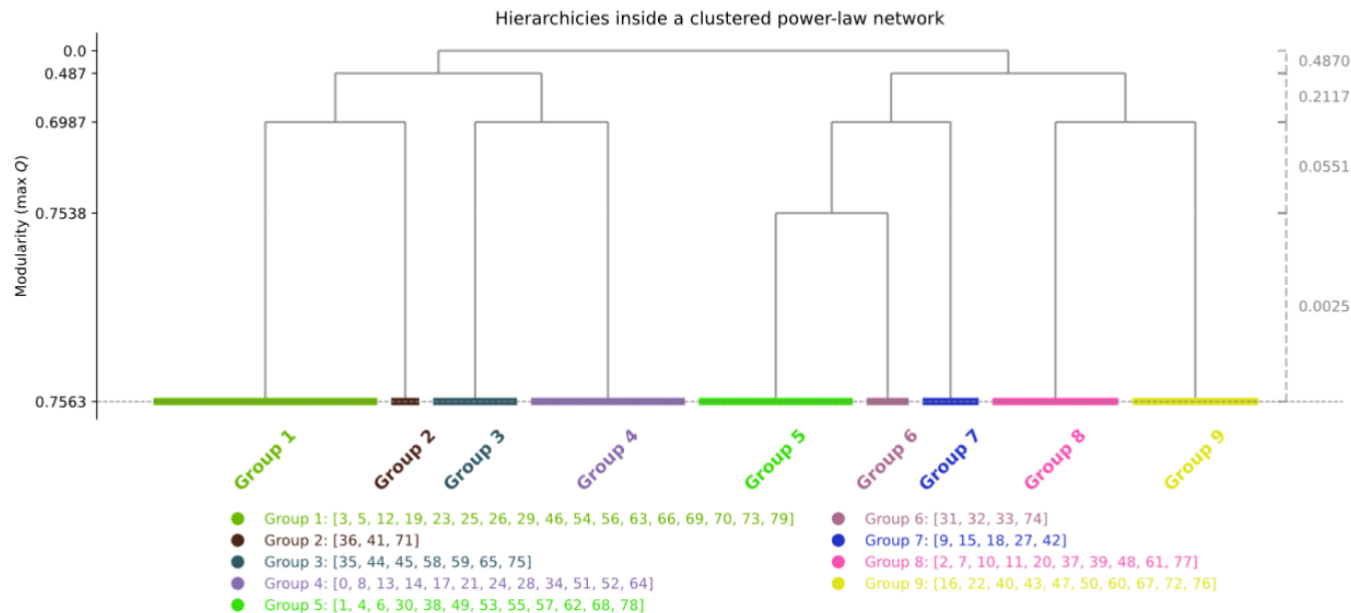
It enables experiments to be conducted in a standardized way thanks to a simplified interface.



# Qommunity library

The library allows us to visualize data. Here are some of them:

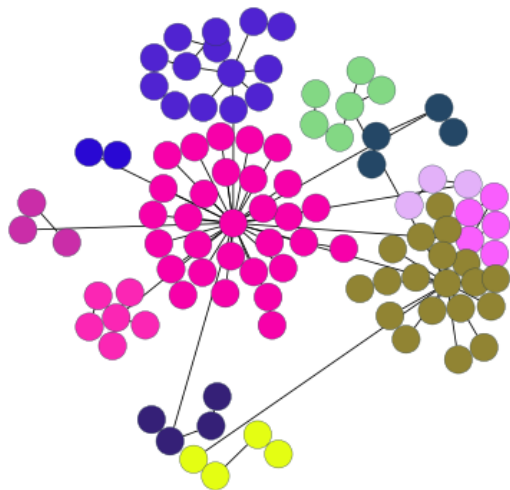
## Dendrogram



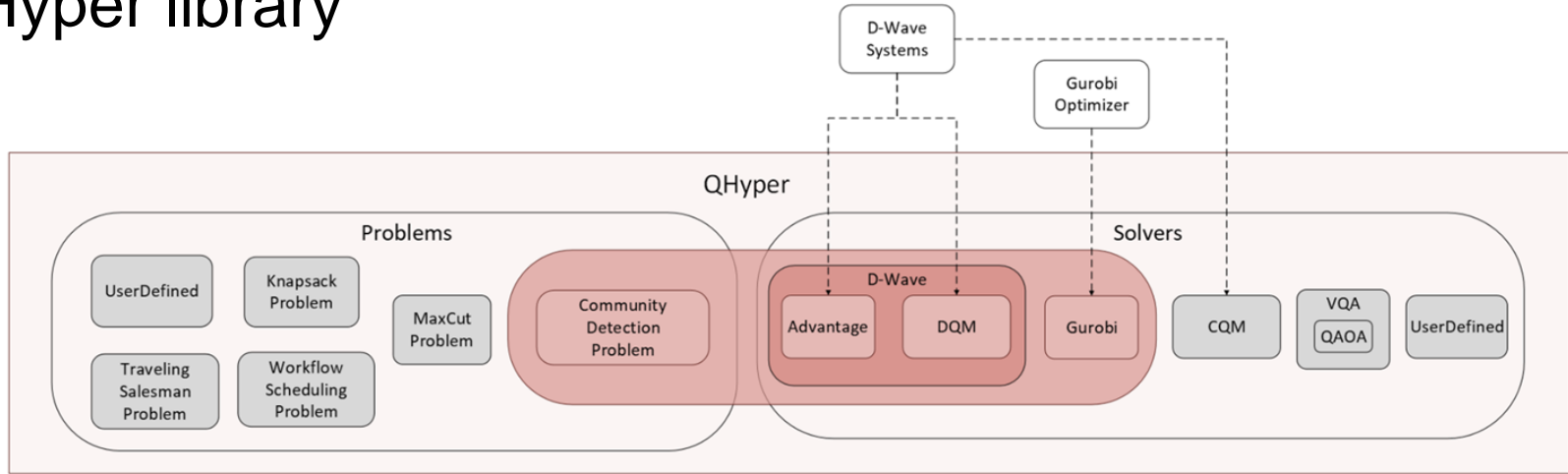
# Qommunity library

The library allows us to visualize data. Here are some of them:

## Communities visualization



# QHyper library



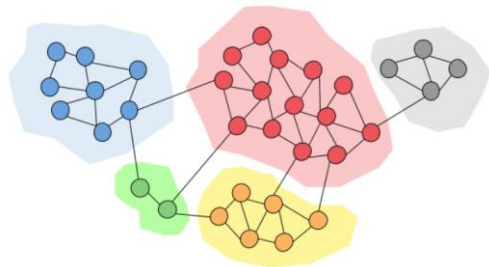
**QHyper** is a library designed to perform optimization experiments using quantum and classical methods

It consists of three main components: **problems, solvers and optimizers.**



# QHyper library - what we have implemented

## Problems



Community detection problem

## Solvers:

**D:wave**

The Quantum Computing Company™

**Advantage** - quantum solver

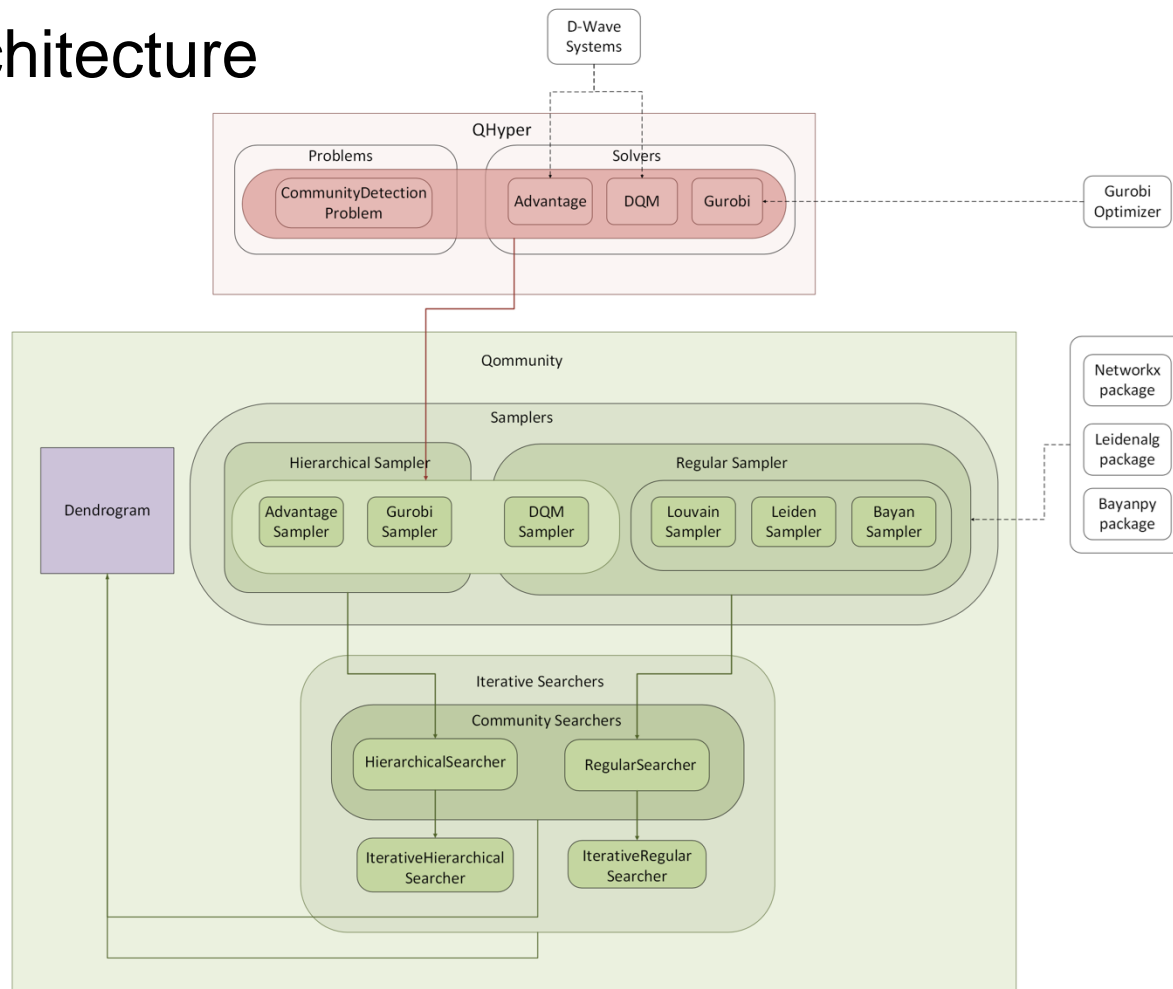
**DQM** - hybrid solver



**GUROBI**  
OPTIMIZATION

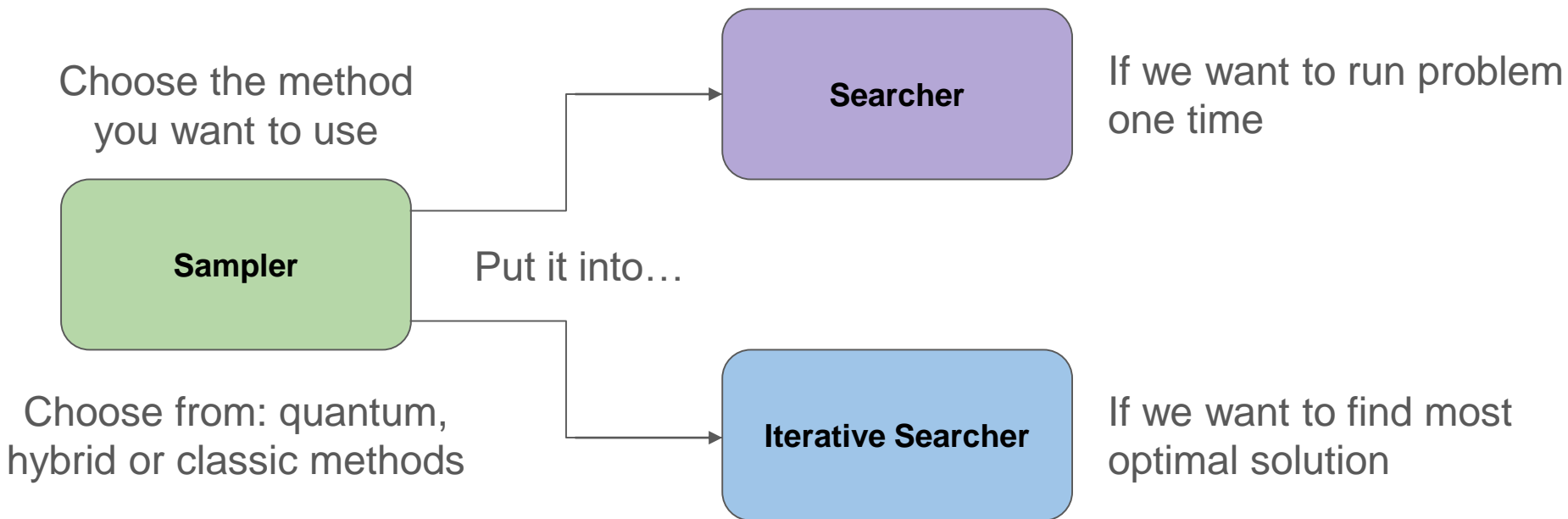
**Gurobi** - classical solver

# System architecture

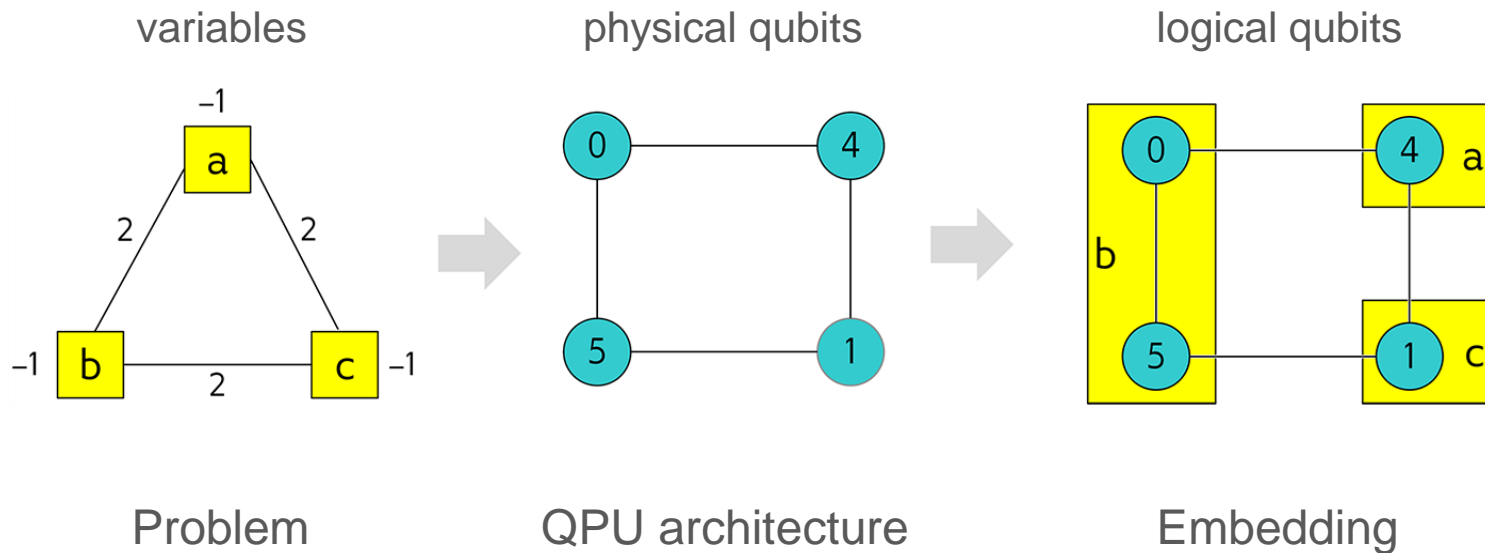


# Qommunity library - Modules

There are three modules: **Sampler**, **Searcher** and **Iterative Searcher**



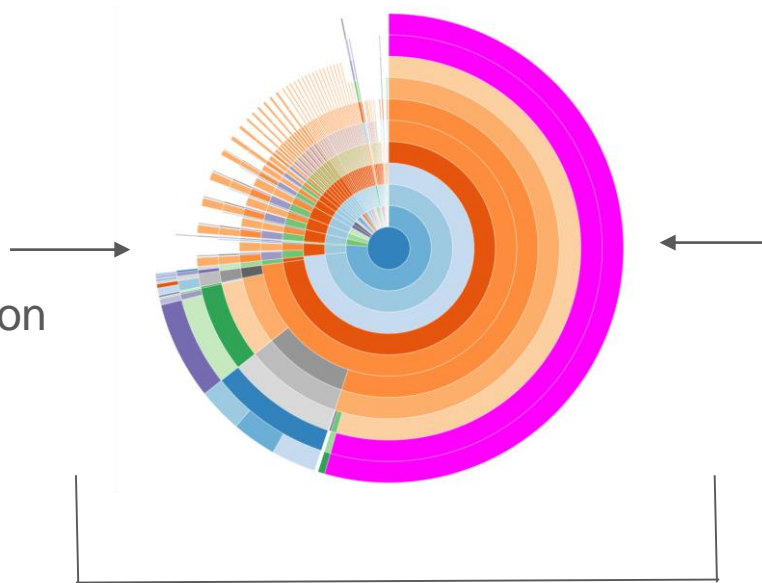
# Minor-embedding



## Code profiling and minor-embedding process

other times, including:

- calculation of modularity matrix, QUBO formula, —
- cloud communication with the solver

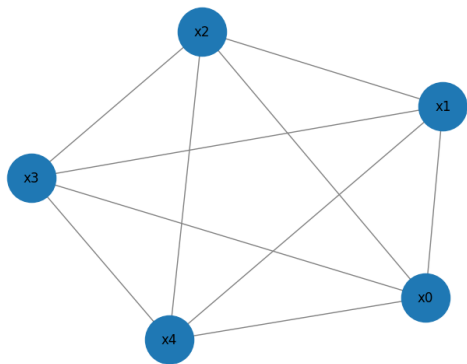


time of determining  
standard minor-  
embedding

execution time of the hierarchical method  
with Advantage solver

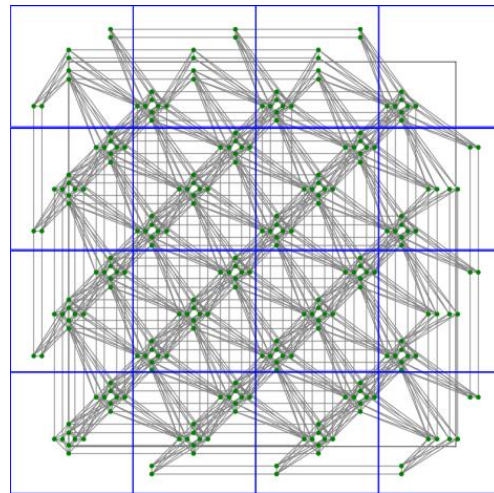
# Minor-embedding process

Source graph



QUBO problem formulation represented as a graph.

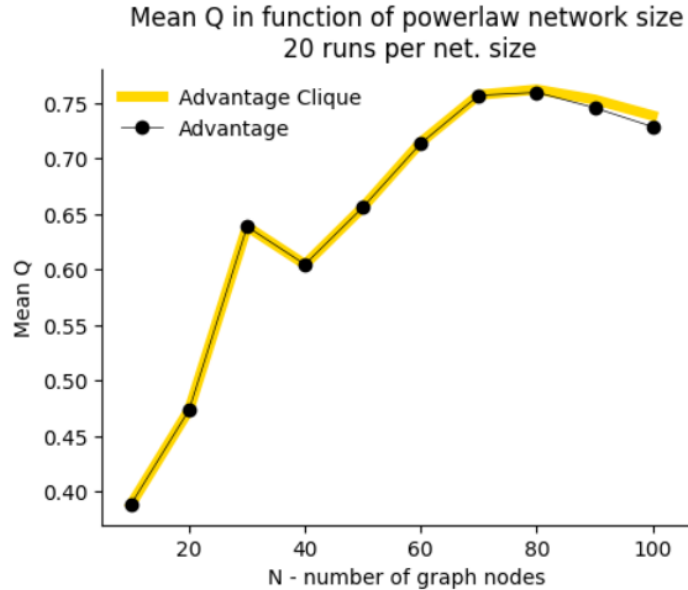
Target graph- the QPU architecture topology



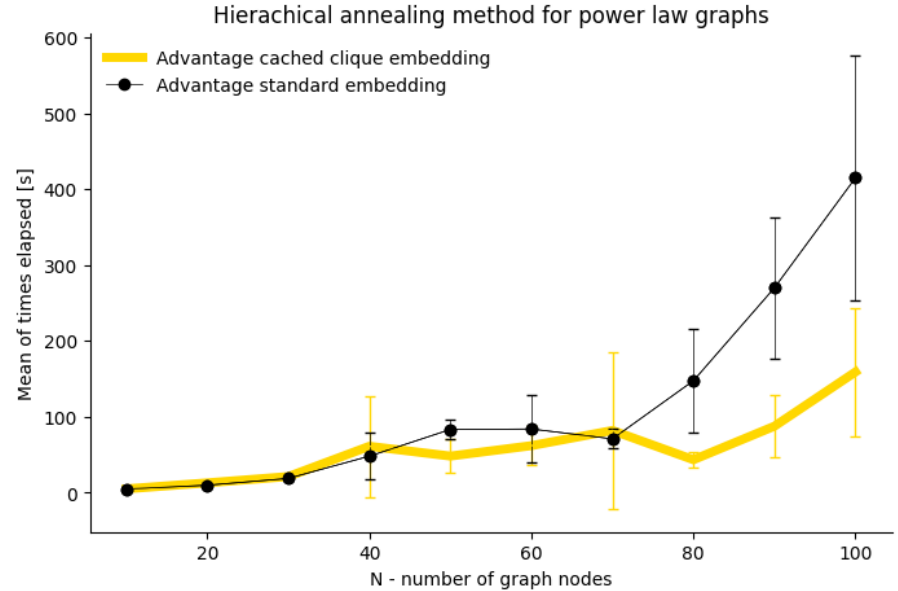
Unit cells of the Pegasus topology in a  $P_4$  graph, with qubits represented as green dots and couplers as gray lines.

# Minor-embedding - embedding the problem graph in the QPU graph

## Stability of results



## Reduced operating time



# Project Summary

article is in review in a journal called *IEEE Transactions on Network Science and Engineering*:

*“Modularity maximization and community detection in complex networks through recursive and hierarchical annealing in the D-Wave Advantage quantum processing units”*

## Paper



[arxiv.org/abs/2410.07744](https://arxiv.org/abs/2410.07744)

## Library



[github.com/kacper3615/Qcommunity](https://github.com/kacper3615/Qcommunity)

