Quantum pathfinder: the vehicle routing optimal solver

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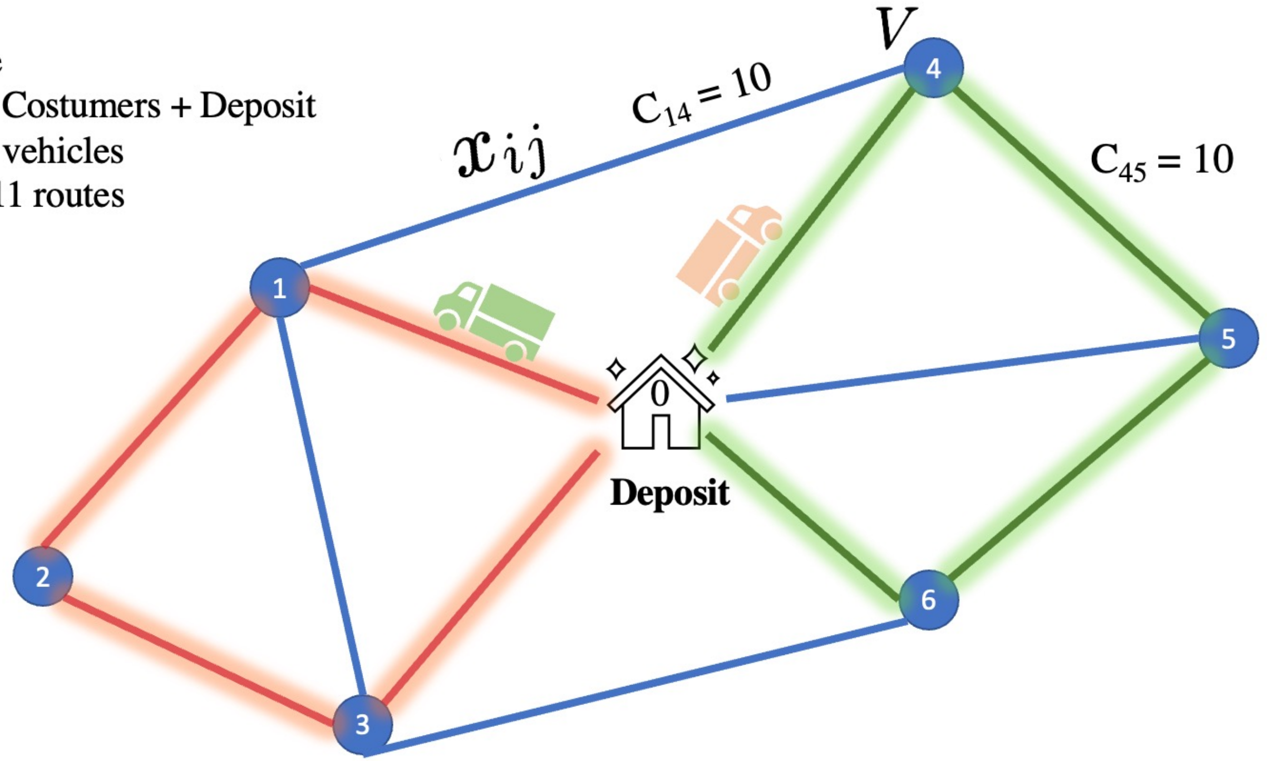
Objective

Quantum pathfinder is an optimization tool designed to find the optimal set of routes for a number of vehicles to traverse in order to deliver to a given set of customers. Quantum Pathfinder uses a quadratic unconstrained binary optimization (**QUBO**) representation of the well-known problem of the Vehicle Routing Problem [VRP](VRP) and solves it using the Quantum Approximation Optimization Algorithm **(QAOA)**. We compare the results using QAOA and CPLEX a classical solver.

Example
- V = 6 Costumers + Deposit
- K = 2 vehicles
- X_{ij} = 11 routes



Cost Function

$$\min \sum_{i\in V}\sum_{j\in V} c_{ij}x_{ij}$$

c_{ij} Cost of going from costumer i to costumer j

x_{ij} Binary variable 1 if route i, j is considered in the solution

V Costumers

Constraints

$$\sum_{i\in V} x_{ij} = 1 \quad \forall j \in V\setminus\{0\}$$

$$\sum_{j\in V} x_{ij} = 1 \quad \forall i \in V\setminus\{0\}$$

To ensure there is one route entering costumer i and leaving costumer j

$$\sum_{i\in V} x_{i0} = K$$

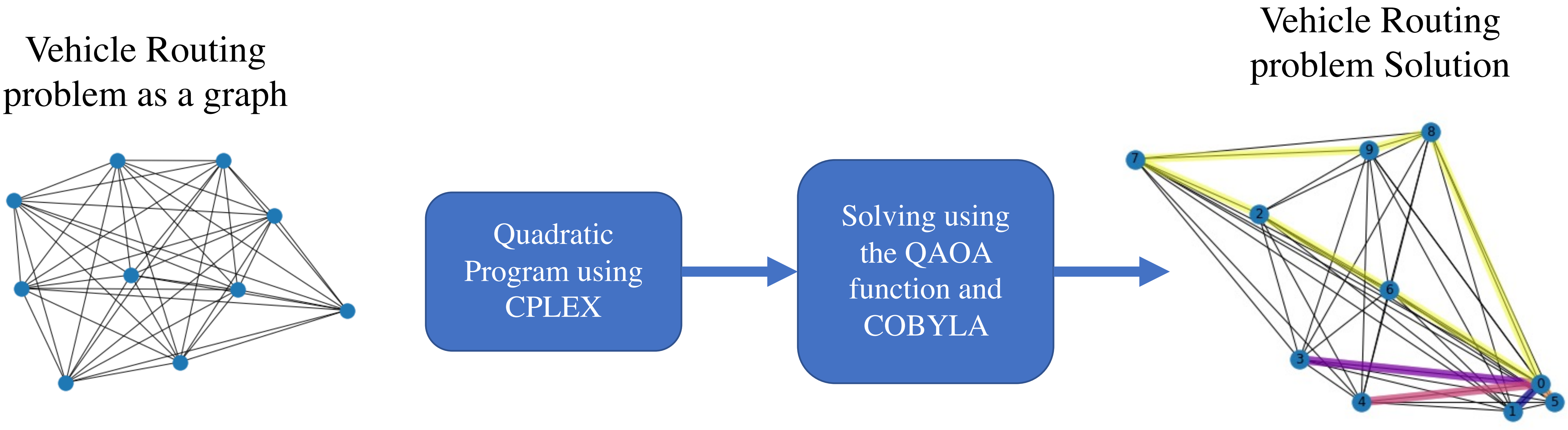
$$\sum_{j\in V} x_{0j} = K$$

Constraints associated with K vehicles leaving the deposit and returning to it.

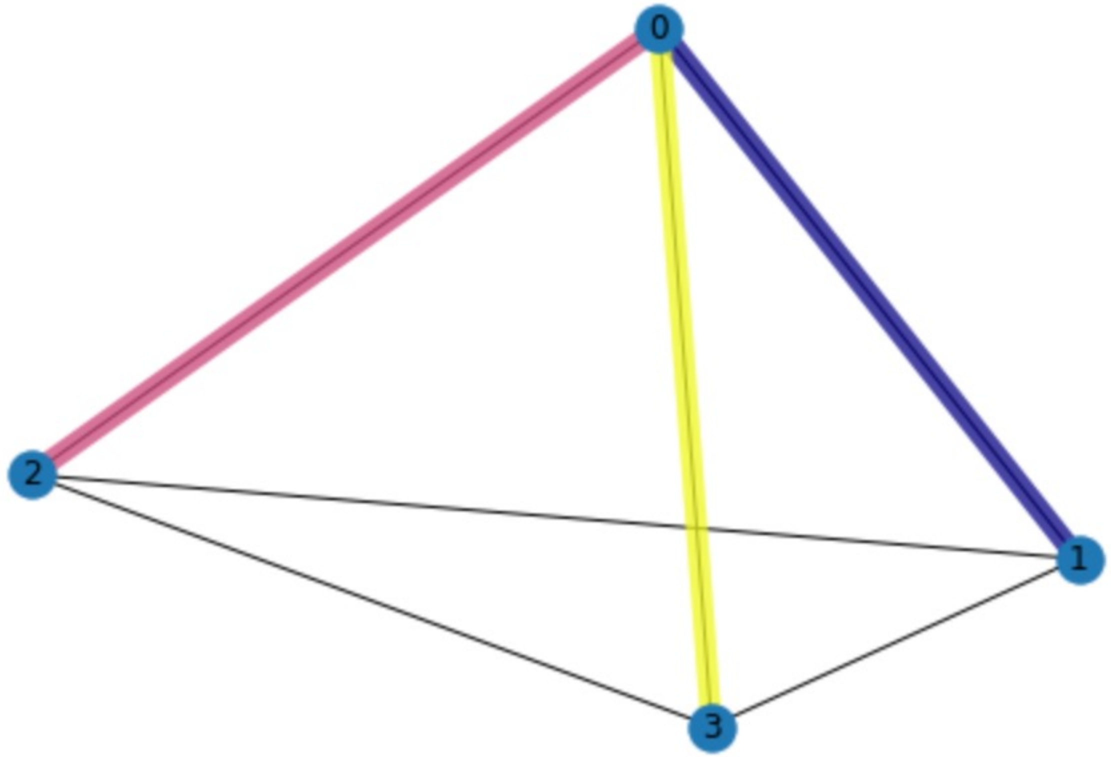
$$\sum_{i\notin S}\sum_{j\in S} x_{ij} \geq r(S), \quad \forall S \subseteq V\setminus\{0\}, S \neq \emptyset$$

$$x_{ij} \in \{0,1\} \quad \forall i,j \in V$$

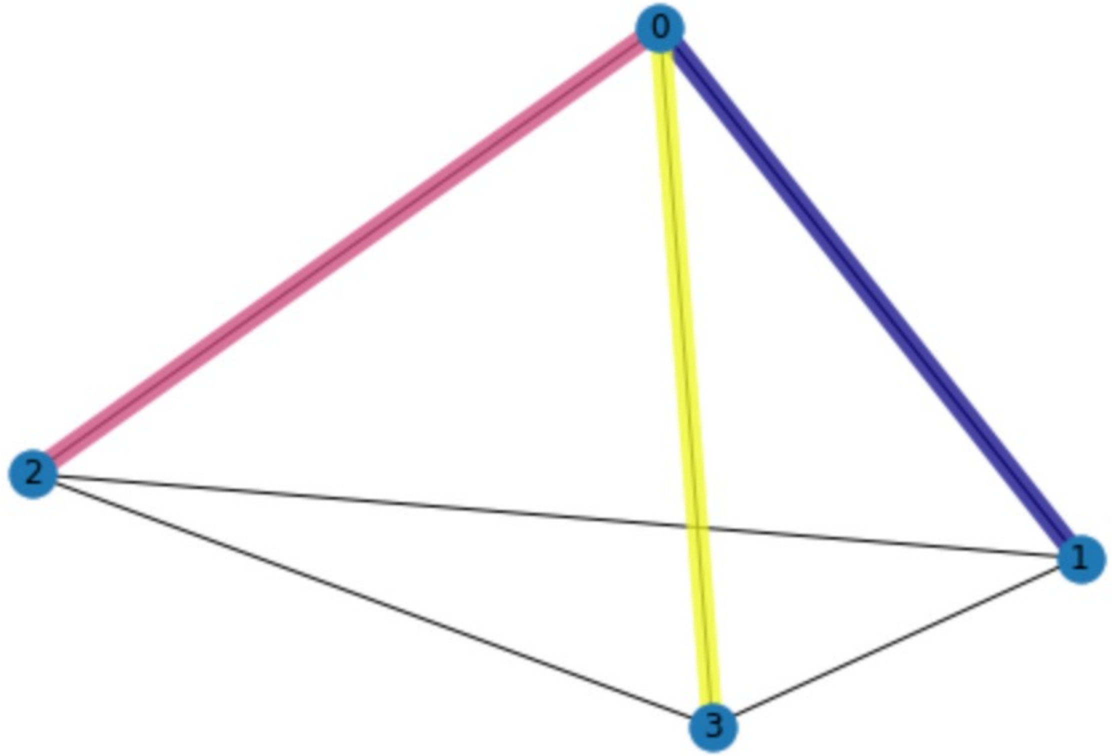
This imposes that the routes must be connected


Vehicle Routing problem as a graph
Quadratic Program using CPLEX
Solving using the QAOA function and COBYLA
Vehicle Routing problem Solution

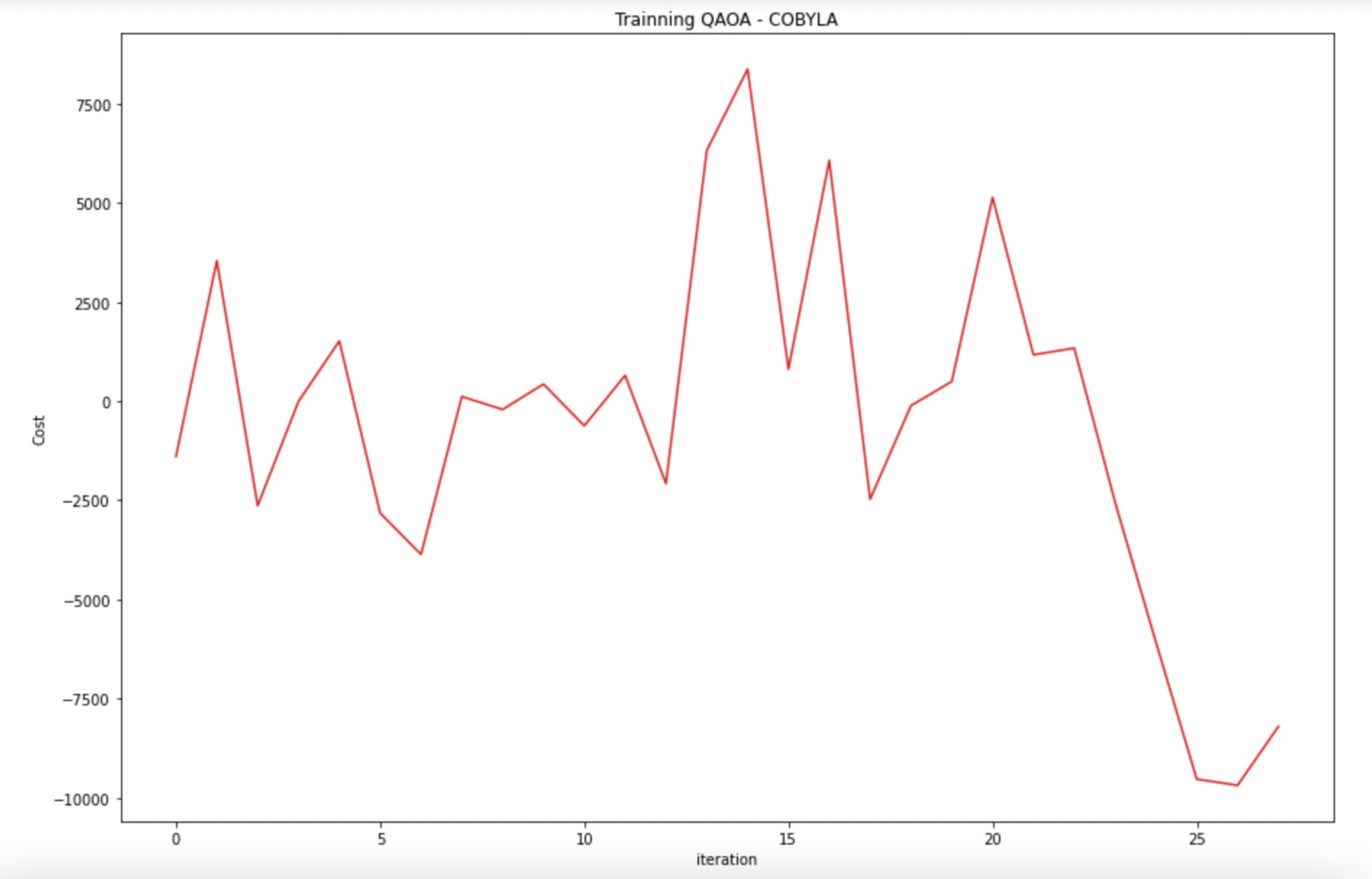
Solution using CPLEX



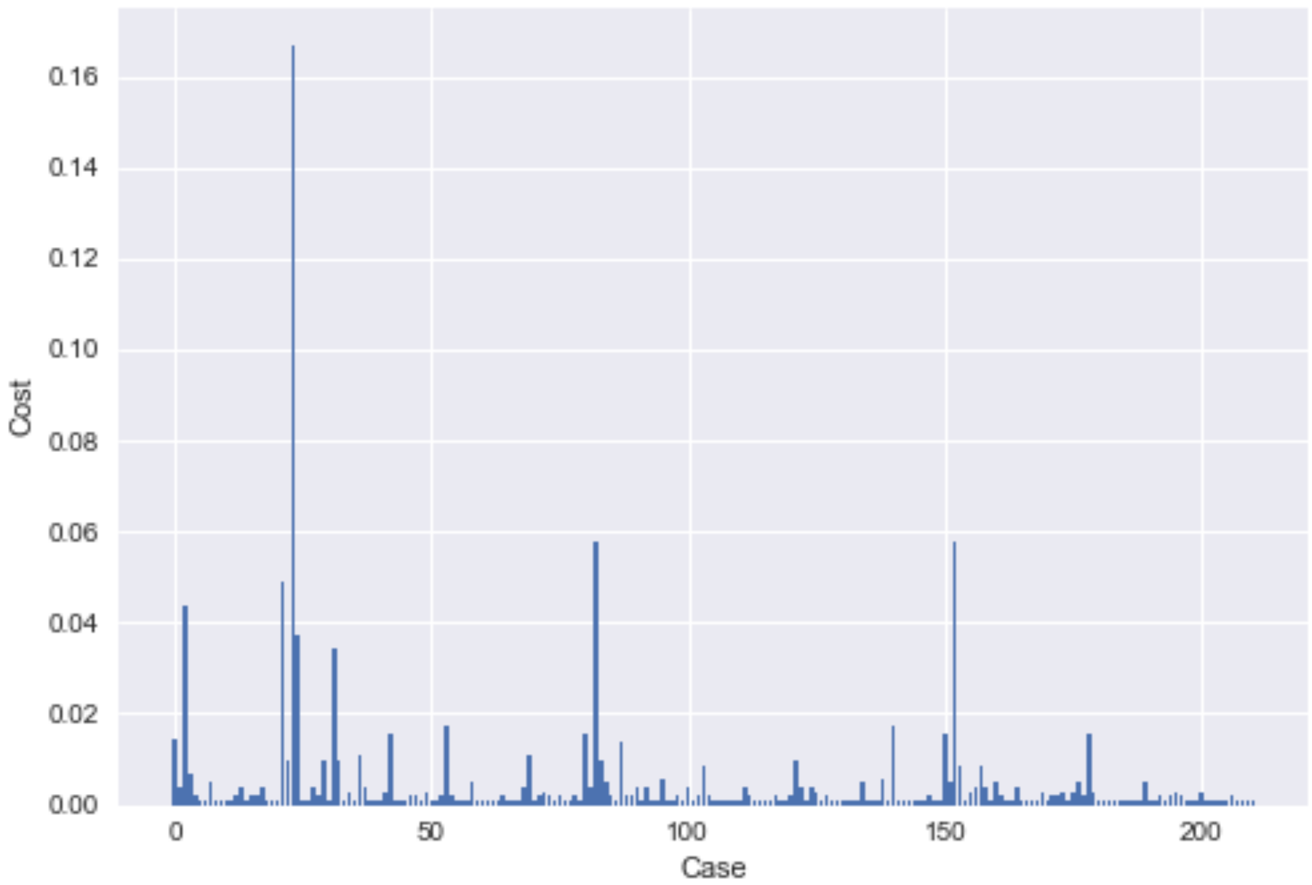
Solution using QAOA and COBYLA



Cost function training



AWS solution



Conclusions

- The QAOA algorithm gives the same solution as CPLEX for the problem proposed which means that the QAOA is getting the optimal solution for this problem.
- The Pennylane solution needs an improvement to classify the correct solution. However, we create a function that combines a model from CPLEX QuadraticProgram and pennylane. This tool will be helpful for a easier user interface to encode QUBO problems.
- Future work involves using real devices with error mitigation