UK Quantum Hackathon

Organised by the National Quantum Computing Centre

University of Warwick, 22nd to 24th July 2024

Challenge provider: BT

Quantum providers:

Emulator	Primary device	Backup device
D-Wave	D-Wave	AWS (IQM) + Classiq

TEAM 1: Efficient Placement of Transmitters, Receivers and Sensors in Networks

Problem Description and Background

Company:

BT, one of the world's leading communications services companies, serves the needs of customers in the UK and in 180 countries worldwide. The networks division are responsible for planning the technology and logistics that back up many of the services provided. Doing this competitively means optimising the performance of network elements (hard engineering problems), and networks planning (involving many types of optimisation and constraint satisfaction problems.)

The goal is to optimise the position of antennas / sensors to provide good coverage efficiently. This can be challenging in complex environments such as urban areas, and along road and rail networks.

Wireless communications in public spaces is a societal benefit, facilitating business and social interaction, and even providing a lifeline in emergencies.

Coverage is a pain point. Customers could become dissatisfied if they do not have coverage in a particular area.

Current Solution

The minimum vertex cover problem is NP Hard, and some examples cannot be solved using linear relaxation (these examples involve constraint matrices which are non-totally unimodular.) Note however, that many instances are not computationally hard to solve, eg problem on a bipartite graph can be solved in polynomial time.

Computational methods that can be applied to solve hard examples of this problem are:

Integer and Mixed Integer Linear Programming. (commonly used) see e.g.

https://opencourse.inf.ed.ac.uk/sites/default/files/2024-03/iads_python_lab6.pdf

Monte Carlo algorithms.

Simulated Annealing.

A computationally hard problem can be represented in a fairly small number of qubits, meaning NISQ quantum computers can be applied, e.g. QAOA or QA - or a completely different approach. It is not known whether quantum computers, or any given quantum computing algorithm, will provide an advantage to this problem.

Example

If the vertices in the graph represent potential sites for access points, and the edges in the graph represent sites which can 'handover' to each-other (i.e. cell edges are in range of eachother), then a minimum vertex cover can be used to identify an efficient set of cell sites which provide coverage and have the ability to hand over to eachother. (This approximation works reasonably well as long as the cell sites are regularly spaced or otherwise constrained, for example along a network of roads).

We will provide two synthetic example, representative of a real world scenario, one of which is hard to solve classically.

Problem variants include:

- Requirement for resilience: Can you find two non-overlapping vertex sets which both provide 'vertex cover', such that the overall number of vertices in the two sets is minimal?

- Adjusting for cost of site: We weight the vertices according to the cost of each site. Can you find a minimum cost placement?

Literature

The problem class also has other applications, e.g. optimum placement of lidar sensors around roads to detect traffic speeds, and the positioning of beacons for time dissemination.

Yann Briheche, Frédéric Barbaresco, et al. Theoretical Complexity of Grid

Cover Problems Used in Radar Applications. Journal of Optimization Theory and Applications, 2018

Yigit, Yasin, et al. 'Self-Stabilizing Capacitated Vertex Cover Algorithms for Internet-of-Things-Enabled Wireless Sensor Networks'. https://doi.org/10.3390/s22103774.

[Variant of the minimum vertex cover is used for adhoc data transmission network between IoT sensor nw]

Dagdeviren, Zuleyha Akusta. 'A Metaheuristic Algorithm for Vertex Cover Based Link Monitoring and Backbone Formation in Wireless Ad Hoc Networks'. https://doi.org/10.1016/j.eswa.2022.118919.

Pelofske, Elijah, et al. 'Solving Large Minimum Vertex Cover Problems on a Quantum Annealer'. https://doi.org/10.1145/3310273.3321562.