Pasqal Assignment

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Quantum computing with neutral atoms

1 Introduction

For this assignment, we have to find the best possible configuration of frequencies for a given set of antennas to prevent any interferences between them using the least possible different frequencies.

We can model this problem by a graph where the nodes match the positions of the antennas and the edges match the possible interferences between two close antennas, in our case we will draw an edge when the antennas are less than 8.7km away from each other.
Then the problem can be seen as the famous graph-coloring problem where we need to find the minimum number of groups of nodes for each connected node to be in a different group.

1.1 Boilerplate

To get started with this project, we used the files given in the GitHub repository (In particular `MIS_adiabatic.ipynb`), so we already had the pulse generation, MIS and graph with blockage done in advance.

2 Main idea

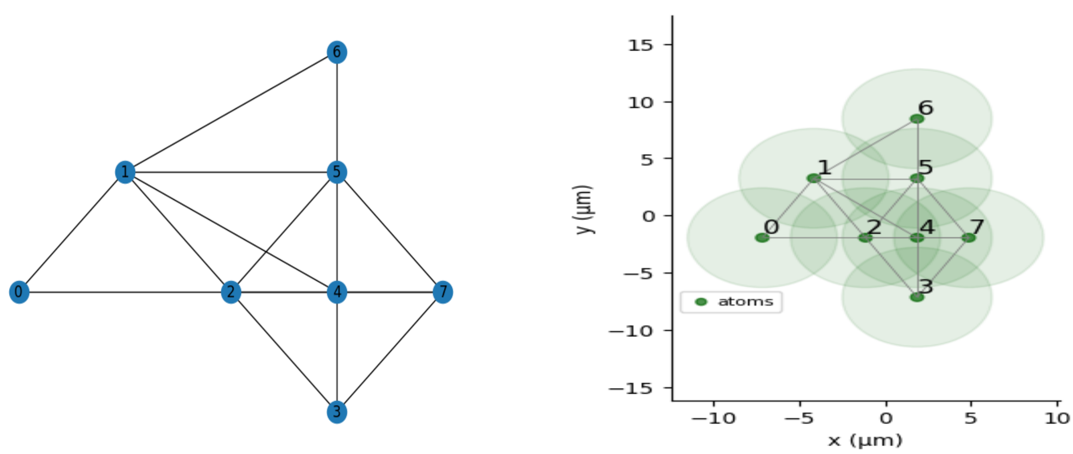
We've seen in class how to solve an MIS problem using Pulser akin to find the best configuration of two groups separating the most nodes and the solution adopted in this report is to use this MIS solver multiple times to separate the atoms into more than two groups.
Here are the steps of the algorithm:

- Use the positions of the antennas to get a graph
- Create the pulse used in the MIS solver
- Use the MIS solver to separate the atoms in 2 groups
- Reapply the MIS solver on the subgroups until no nodes are connected in the subgroups

3 Implementation

3.1 Atoms layout

Here is the graph matching our problem and the atoms layout used in Pulser:



(a) Classic Graph

(b) Pulser atoms layout

Figure 1: The graph modeling our problem and the Pulser atoms layout implementation side by side

3.2 Pulse creation

Next, to implement the MIS solver we've created a function adding the needed pulses to a sequence in Pulser, we've decided to keep the pulses argument as seen in class with no changes.
Here is the exact sequence of pulses used in the MIS solver:

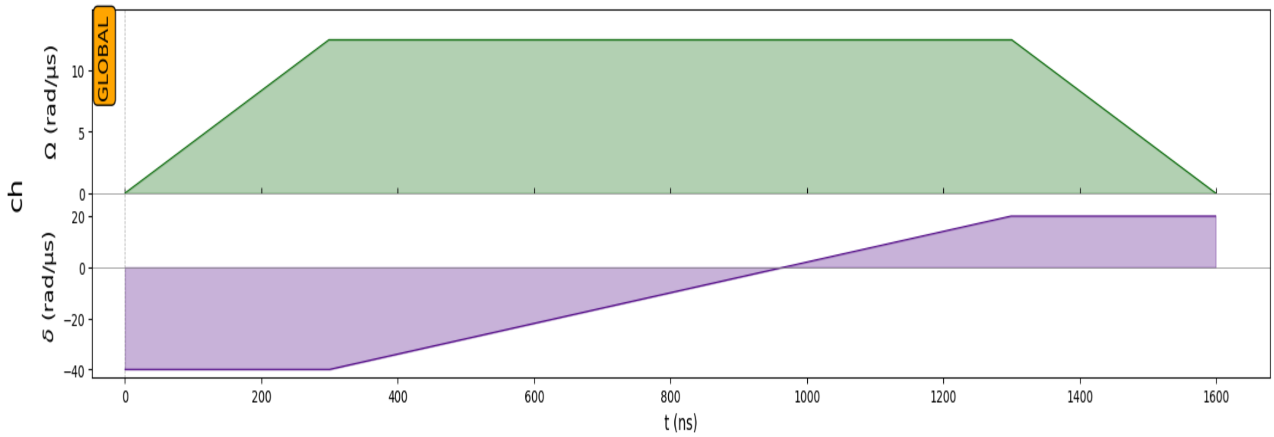
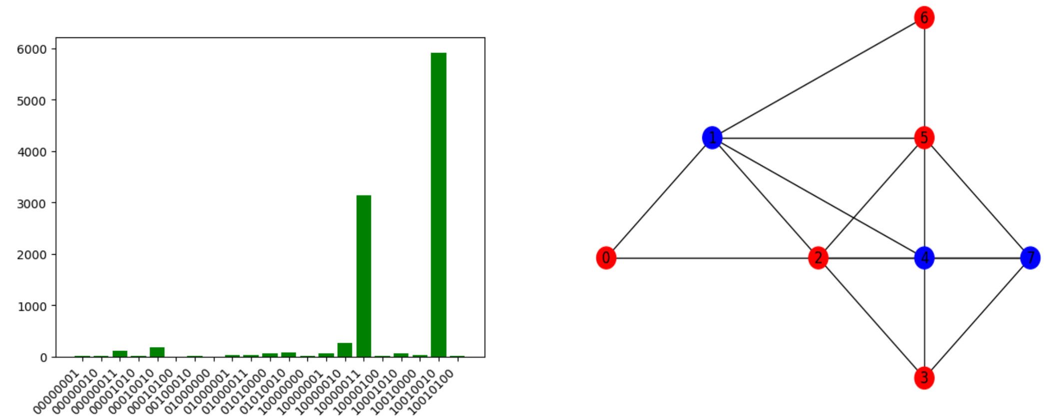


Figure 2: MIS solver sequence

3.3 MIS solver

Then we apply our sequence using a backend and get the results over 1000 shots, The most measured state will give us the most likely configuration to solve the MIS problem, using this measure we can separate our results in two distinct groups.



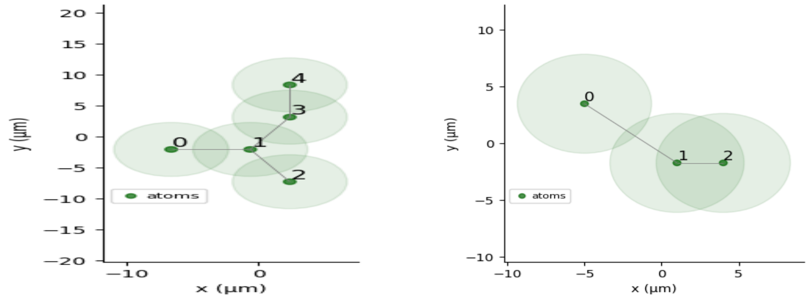
(a) MIS measures

(b) First group separation

Figure 3: The MIS measures and group first 2 groups

3.4 MIS on the subgroups

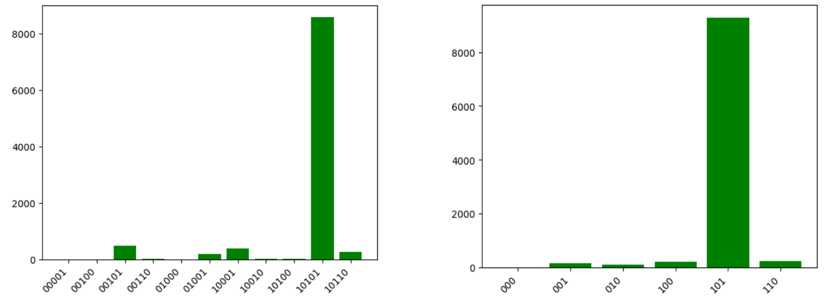
Since both groups one and two have connected nodes in them, we need to reapply the MIS on both. So we create two new graphs for the subgroups.



(a) First subgroup atom layout (b) Second subgroup atom layout

Figure 4: Atom layout of the two subgroups

And after applying the same sequence of pulses as before on both atoms' layouts we get the measurements.



(a) MIS measurements for the first subgroup (b) MIS measurements for the second subgroup

Figure 5: MIS measurements for the two groups

and here are the results achieved:

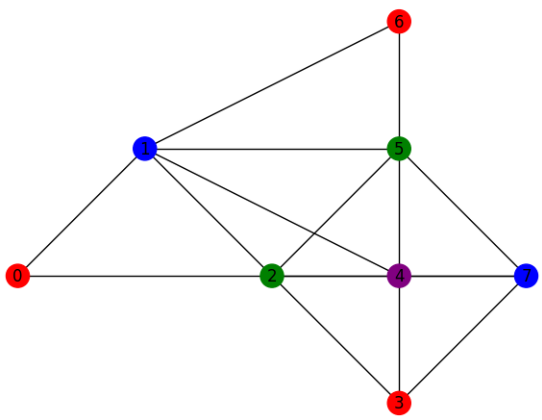


Figure 6: Group found applying MIS twice

4 Looping MIS

As we can see on the graph above, there is still one group with connected Nodes in it, but since for a more complex antenna setup we might have to repeat since process a great number of times we've created a recursive loop calling the MIS solver on the subgroups as long as there are connected nodes in the subgroup by computing the distance between each node.
Here is the result of the loop called on the original graph:

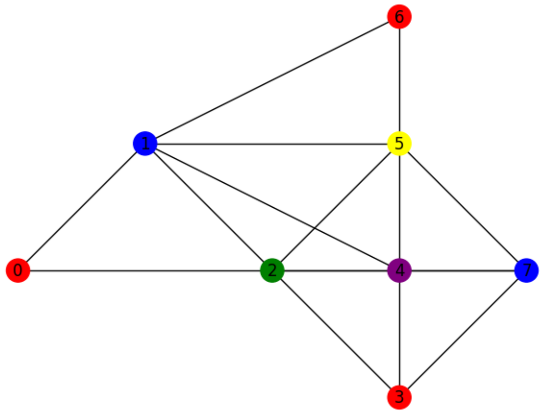


Figure 7: The result found by the looping MIS solver

5 Conclusion

As we've seen the assignment was successfully answered using Pulser, we've matched our antenna setup to an atom layout and by applying a sequence of pulses onto the atom layout to implement an MIS solver, then we've repeated this operation until every close node was separated into different group. This method finds a decent solution but not the optimal solution since we can find another set of antennas using only four groups.