QUANTUM ANNEALING COMPARISION ON DIFFERENT QPU

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Objectives

The goals of this research project is to:

- Understand different approaches of quantum computing.
- Understand the concept of quantum annealing and hybrid quantum computation.
- Implement integer factoring on different quantum computing systems.
- Try to compare the results

Introduction

Quantum computing is an up and coming technology which has gained a lot of potential and advancement in recent times. With companies like IBM, D-Wave, Google etc. allowing public access to quantum computing resources and limitation on different approaches, there are numerous different algorithms and use cases that can be implemented and quantum supremacy over classical computing be achieved. I accessed different platforms and approaches of quantum computing. Since gate based quantum computing has limited number of quantum bits or qubits, I was particularly interested in quantum annealing approach.
I researched the math of quantum annealing and implement it on D-Wave and Rigetti Systems quantum computer.

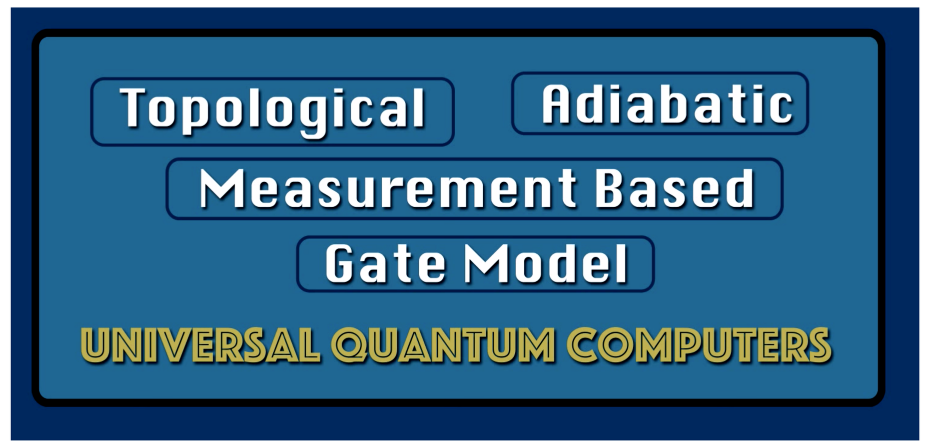

Figure 1:Universal Quantum Computer

Universal Quantum Computer

A universal quantum computer is one where gate model approach can be mapped to other approaches in polynomial time. Various approaches to quantum computing are:

- Gate Based
- Measurement Based
- Topological
- Adiabatic

D-Wave works on adiabatic quantum computing using quantum annealing. It has 2038 qubits.
Rigetti's quantum computer works on gate based model and has a concept of lattice, where a lattice is connected qubits which can go upto 18.

Quantum Annealing

In quantum annealing, we simulate the problem and all possible outcomes for a given problem are calculated. The soultion is based on minima of the nenrgy graph of the quantum system. To provide bias, magnetic fields are applied, this bias being the constraints we want our solution to satisfy.
Quantum annealing uses hamiltonian framework, the system must remain in ground state during simulation and operation. Hamiltomian framework is given by:

$$\mathcal{H}_s(s) = \frac{-1}{2}\sum_i \Delta(s)\sigma_i^x + \epsilon(s)(-\sum_i h_i\sigma_i^z + \sum_{i<j} J_{ij}\sigma_i^z\sigma_j^z)$$

Important Result

On D-Wave, the results were observed, after 20 runs, the results were at different energy levels, though consistent in terms of factors.
Hybrid approach on Rigetti was not finished.

D-Wave

For adiabatic quantum computing using quantum annealing, integer factoring was implemented based on D-Wave using their example sample given on LEAP.

1. Formulate the problem as constraint satisfaction problem.
2. Convert the model to binary quabratic model
3. Run on quantum processing unit.
4. Observe the results for factoring from 1 to 61.

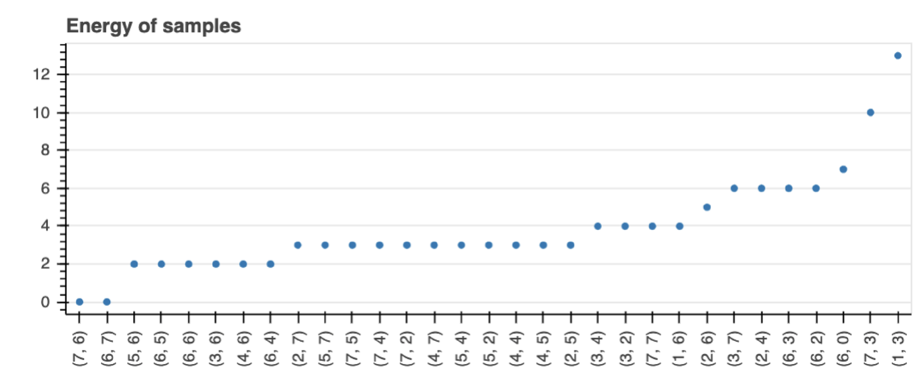

Figure 2:D-Wave result for a large number

Rigetti

On Rigetti, using their FOrest SDK and pyquil, the implementation was not finised. The figure below shows solution graph for a sample problem on Rigetti.

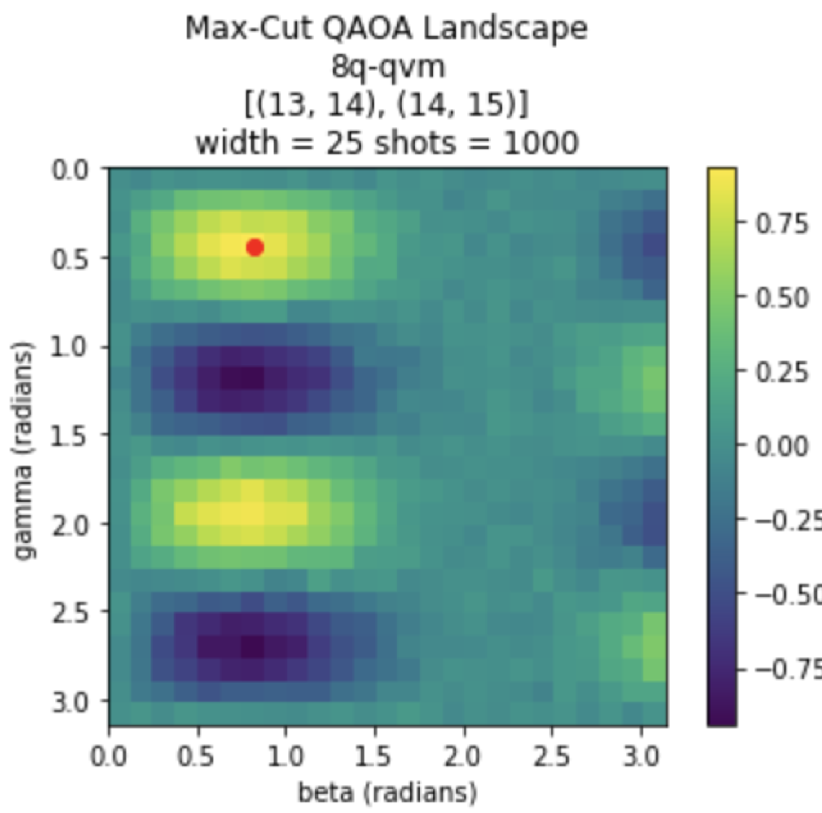

Figure 3:Sample Rigetti result

Gates for Quantum Computer

Gate	Transformation on Bloch sphere (defined for single qubit)
X	π-rotation around the X axis, Z→−Z. Also referred to as a bit-flip.
Z	π-rotation around the Z axis, X→−X. Also referred to as a phase-flip.
H	maps X→Z, and Z→X. This gate is required to make superpositions.
S	maps X→Y. This gate extends H to make complex superpositions. (π/2 rotation around Z axis).
$S^\dagger$	inverse of S. maps X→−Y. (-π/2 rotation around Z axis).
T	π/4 rotation around Z axis.
$T^\dagger$	-π/4 rotation around Z axis.

Figure 4:Quantum Computing Gates

Additional Information

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- Curabitur pellentesque dignissim
- Eu facilisis est tempus quis
- Duis porta consequat lorem

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