D-Wave
The Quantum Computing Company™

The D-Wave Computer
Practical Quantum Computing

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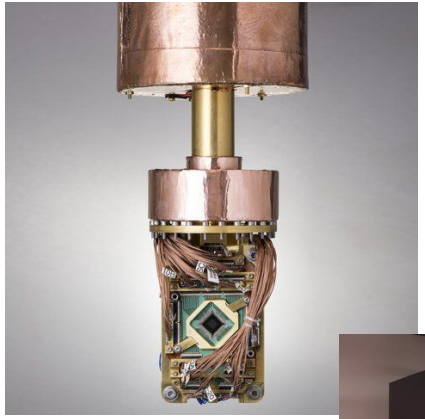
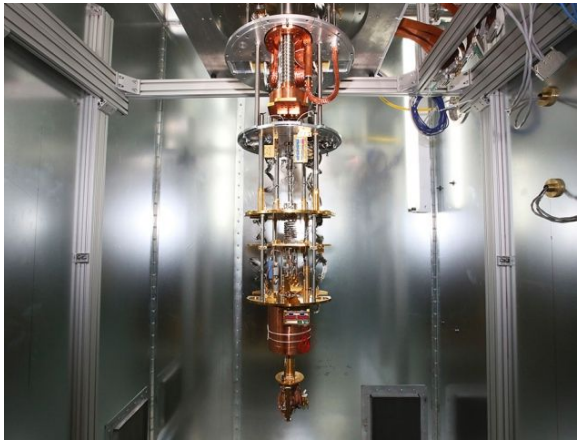
THE UNIVERSITY OF TENNESSEE KNOXVILLE

BIG ORANGE. BIG IDEAS.®

D-Wave Systems

- Canadian Company, 1999
- The world's first company to sell computers to exploit quantum effects in their operation
- Lockheed Martin, Google, NASA Ames, Volkswagen, DENSO, USRA, USC, LANL, and ORNL
- D-Wave machines are quantum computers





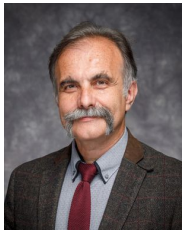
History

Founders

Haig Farris

Geordie Rose

Bob Wiens



Alexandre Zagoskin

2011

D-Wave One

128-qubit chipset using **quantum annealing**

2013

D-Wave Two

Collaboration with NASA, Google and USRA

512-qubit - ML

2015

D-Wave 2X

1000+ qubit

Installed at the Quantum Artificial Intelligence Lab at NASA

2017

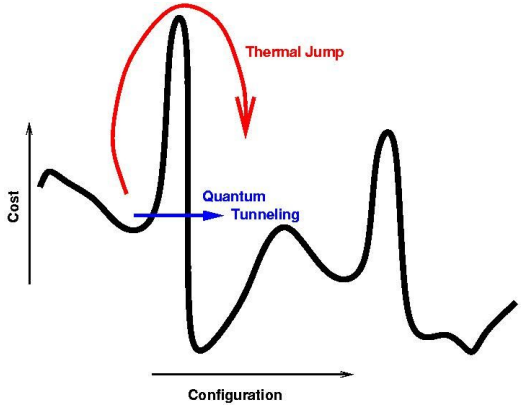
D-Wave 2000Q

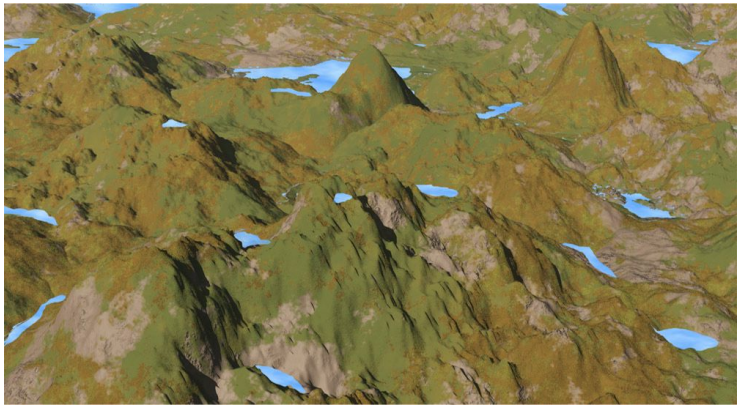
2000 qubit

Open source Qbsolv that solves QUBO problems

How D-Wave Systems Work?

- D-Wave systems use a process called **quantum annealing** to search for solutions to a problem
- Quantum systems tend to evolve toward their lowest energy state
- D-Wave solves problems by searching for the global minimum





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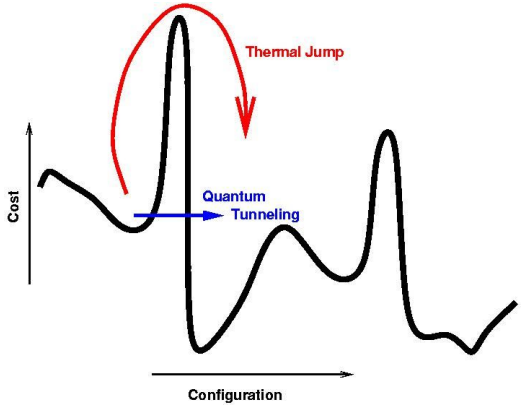
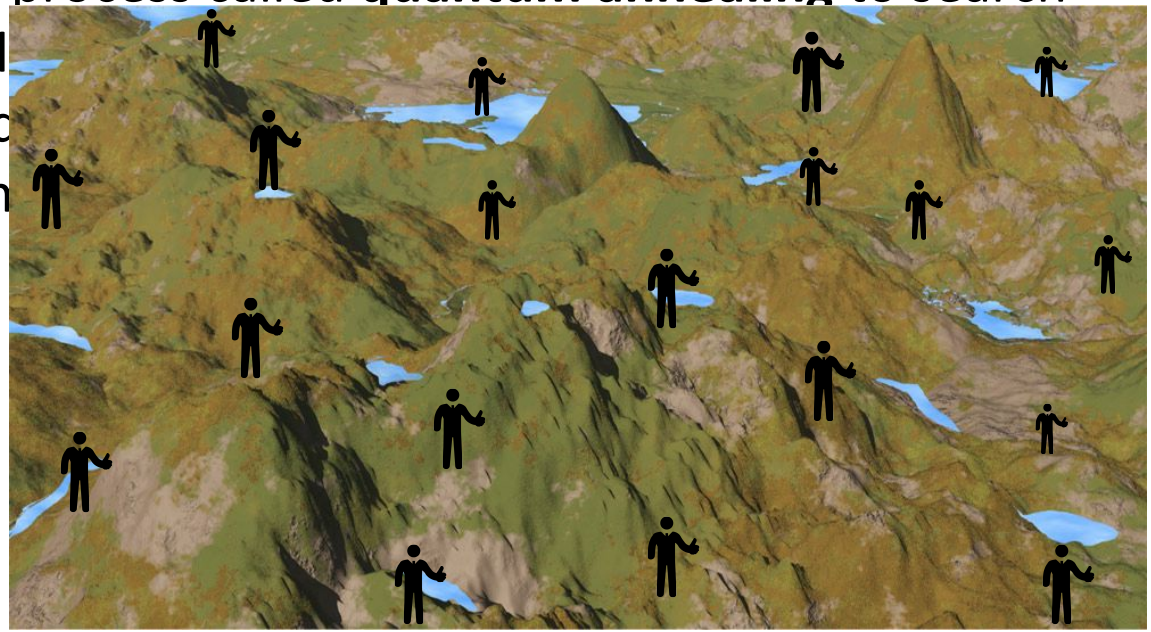


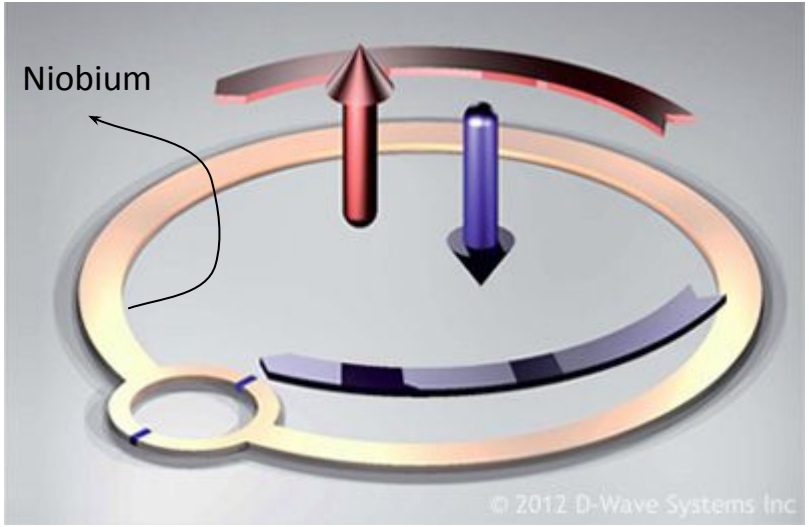


Quantum Annealing

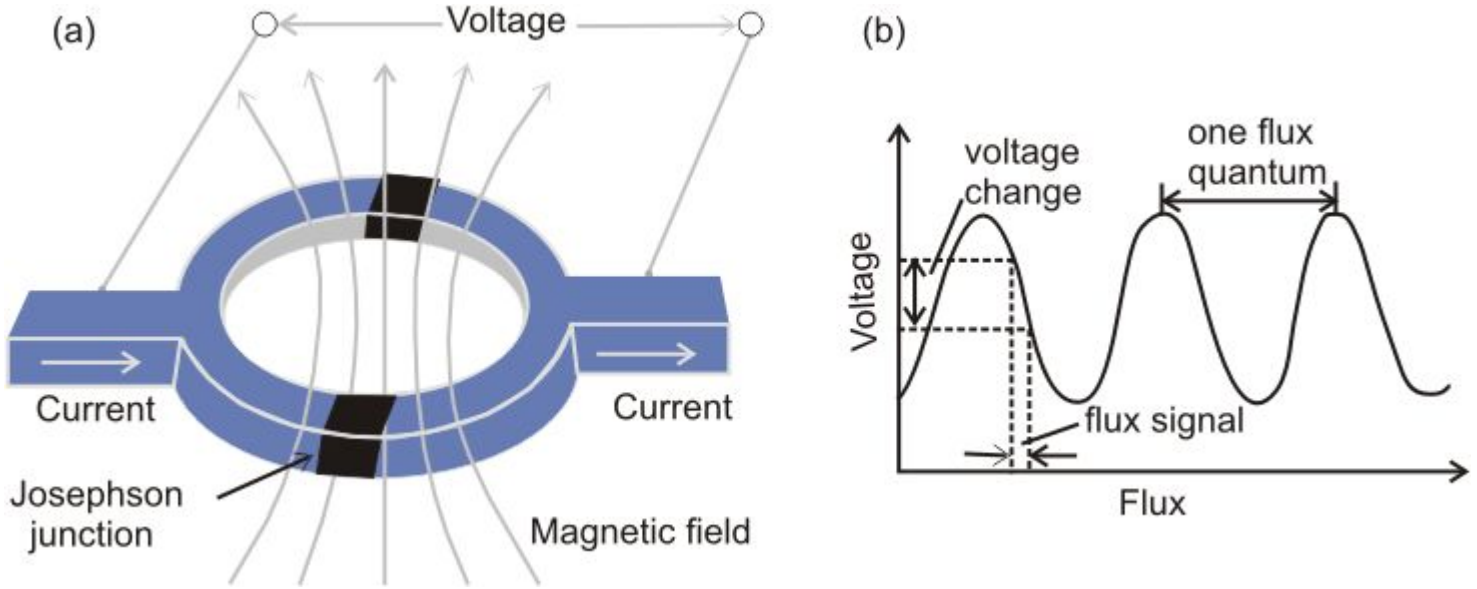
1. Begins with the traveler simultaneously occupying many coordinates (quantum phenomenon of superposition)
2. The probability of being at any given coordinate smoothly evolves as annealing progresses, with the probability increasing around the coordinates of deep valleys
3. Quantum tunneling allows the traveler to pass through hills—rather than be forced to climb them—reducing the chance of becoming trapped in valleys that are not the global minimum
4. Quantum entanglement further improves the outcome by allowing the traveler to discover correlations between the coordinates that lead to deep valleys

D-Wave Quantum Hardware

- CMOS -> SQUID (the basic building block)
- A qubit is a loop made by niobium (superconductor) with a Josephson Junction
- The superconducting qubit structure instead encodes 2 states as tiny magnetic fields, which either point up or down
- There are quantized magnetic field detectors that detect the direction after the anneal is completed



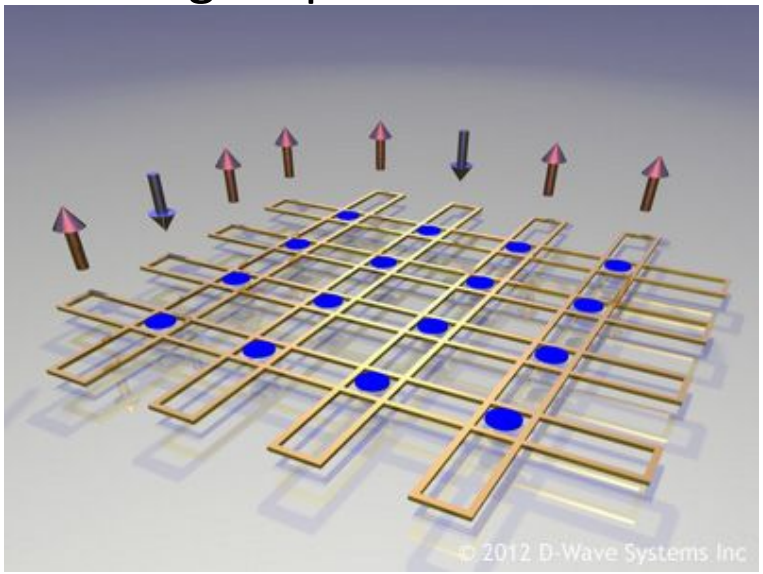
D-Wave Quantum Hardware



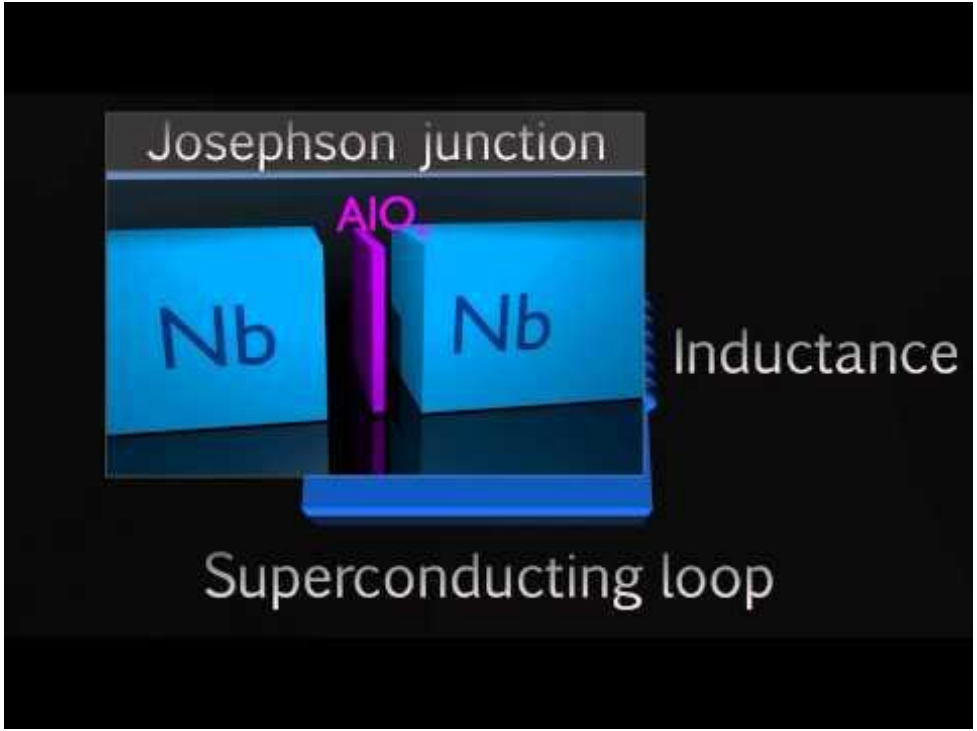
D-Wave Quantum Hardware

- Multi-qubit processor - Couplers connect many single qubits such that they can exchange information
- The couplers are also made from superconducting loops

➔ 8 qubit loops (gold)
➔ 16 coupling elements (blue dots)
➔ these elements couple together variables in a problem that you wish the computer to solve

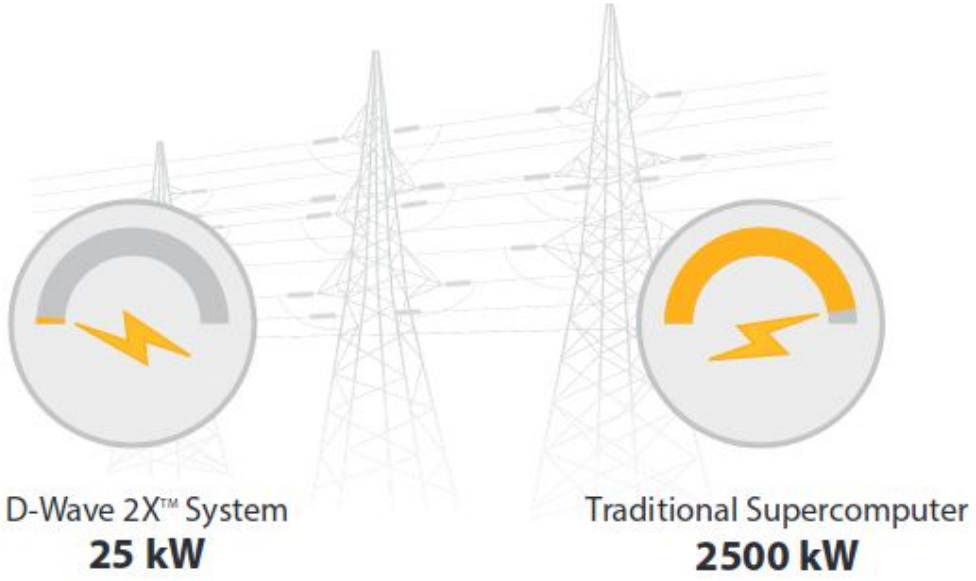


D-Wave Quantum Hardware



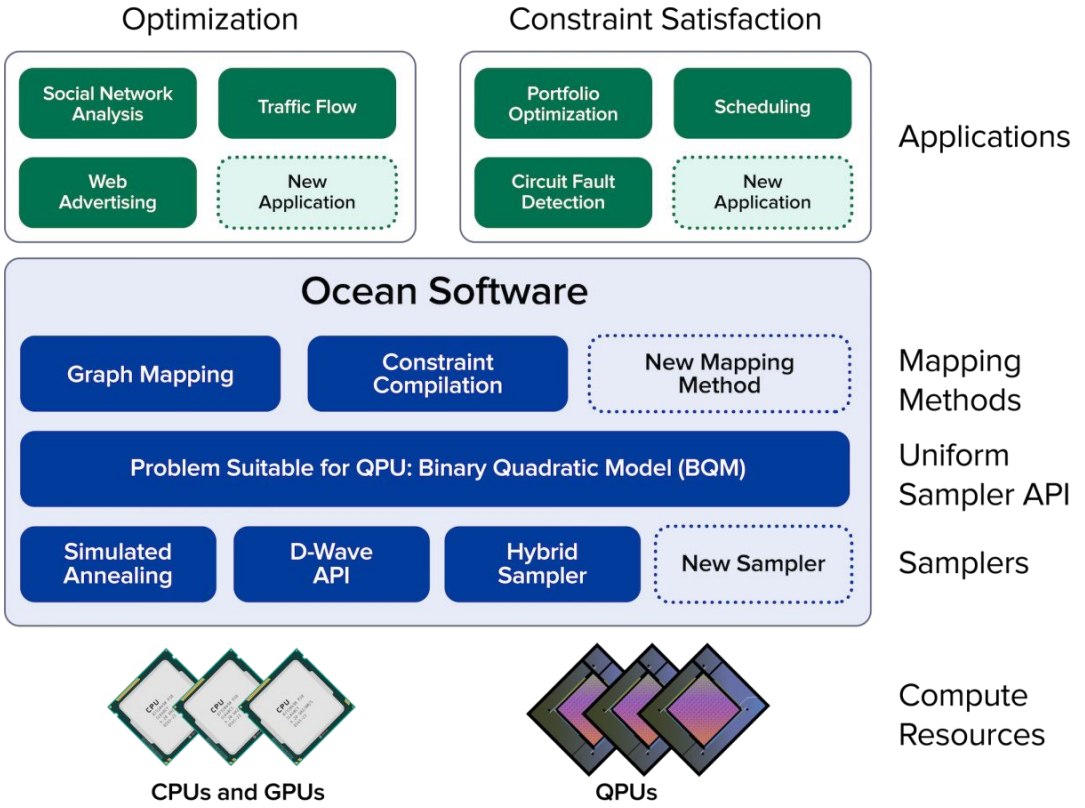
Hardware Potential

- The required air conditioning is one-tenth of what would be expected in a data center for a system with a similar footprint



D-Wave Quantum Software

- D-Wave's Ocean software development kit includes a suite of open-source Python tools on the D-Wave GitHub repository for solving hard problems with quantum computers
- C, C++, Python or MATLAB



D-Wave Leap

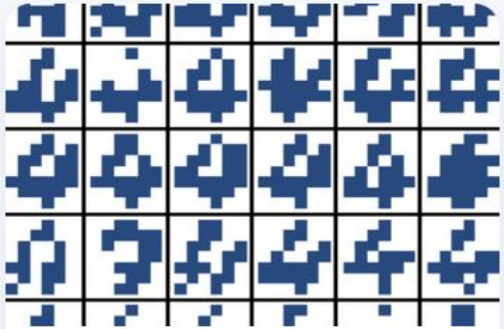
- D-Wave launched Leap™ is a quantum cloud service and Quantum Application Environment (QAE)
- https://cloud.dwavesys.com/leap/

D-Wave Applications: Case Studies

ARTICLE

Volkswagen Group: Optimizing the Travel Time of Taxis in Beijing

www.dwavesys.com



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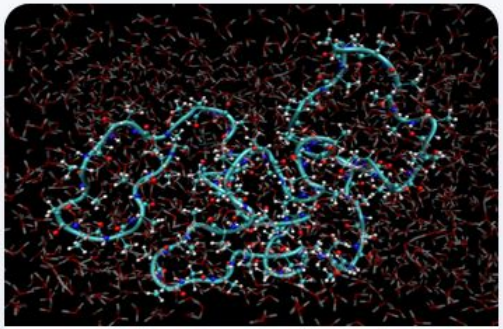
NASA: Quantum-assisted Unsupervised Machine Learning for Digit Recognition

www.dwavesys.com



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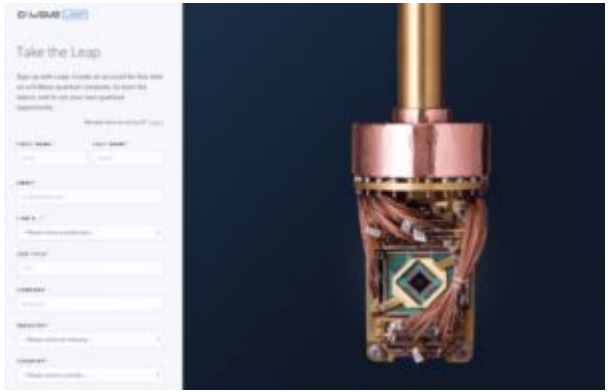
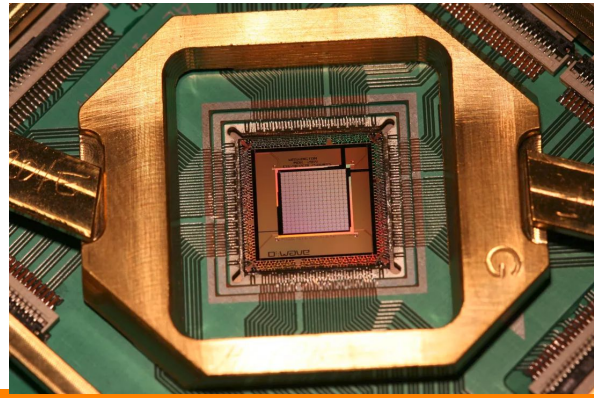
Los Alamos National Lab: Graph Partitioning for Quantum Molecular Dynamics Simulations

www.dwavesys.com

Advantage quantum system

- 5000 Qubits
- Available until mid-2020
- New lower-noise design that will improve performance the scope of problems that can be tackled





D-Wave Downsides

- D-wave's Quantum computers are designed specifically for quadratic unconstrained binary optimisation (QUBO)
- Not purely quantum
- Each qubit in the processor can 'talk' to only six others
- Problems must be rewritten to cope with the limitations of the architecture
- No error correction methods
- Dealing with magnetic interference to increase number of qubits

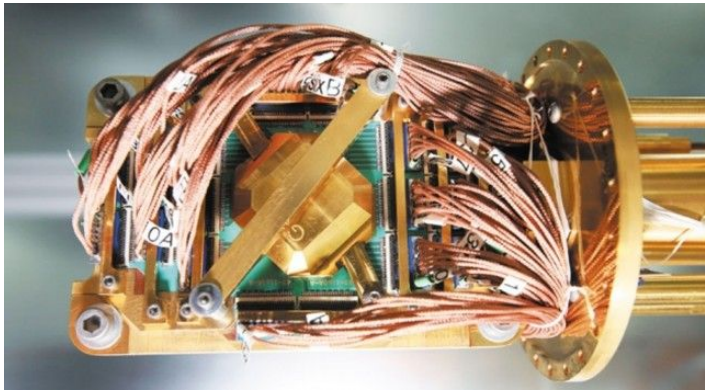
Summary

- D-Wave was the first commercial quantum computing
- D-Wave systems use a process called **quantum annealing**
- The basic block inside the QPU is a **SQUID**
- The SQUID gives a state by creating a magnetic field
- D-Wave has available a machine with 2000+ Qubits
- D-Wave is working on the first 5000 Qubits machine (Advantage)
- There is some controversy about the supremacy over conventional computation

References

- D-Wave 2000 Q: https://www.dwavesys.com/sites/default/files/D-Wave%202000Q%20Tech%20Collateral_0117F.pdf
- D-Wave official website: www.dwavesys.com
- https://www.nature.com/news/d-wave-upgrade-how-scientists-are-using-the-world-s-most-controversial-quantum-computer-1.21353
- https://en.wikipedia.org/wiki/Quantum_annealing
- TechCrunch (News): https://techcrunch.com/2019/02/27/d-wave-announces-its-next-gen-quantum-computing-platform/
- Applications: https://www.dwavesys.com/sites/default/files/D-Wave_Webinar_280519.pdf
- Investors: http://www.dwavesys.com/sites/default/files/D-Wave-Investor%20Presentation-Web100814-2.pdf

Thank you!



Questions?