QQuest Distribution

HAITÍ

Event: Earthquake

Response time: **24-72 HOURS**

2010

2015

CHILE

Event: Earthquake and Tsunami

Response time: **48 HOURS**

PUERTO RICO

Event: Hurricane

Response Time: **DAYS TO WEEKS**

2017

2017

MEXICO

Event: Earthquake

Response time: **24 -72 HOURS**

COLOMBIA

Event: Avenida Torrencial

Response time: **24-72 HOURS**

2021

Studify



Resources distribution **geographically** in an **optimal** way as **fast** as possible in an **emergency**

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Water

~~Resources~~ distribution **geographically** in an **optimal** way as **fast** as possible in an **emergency**

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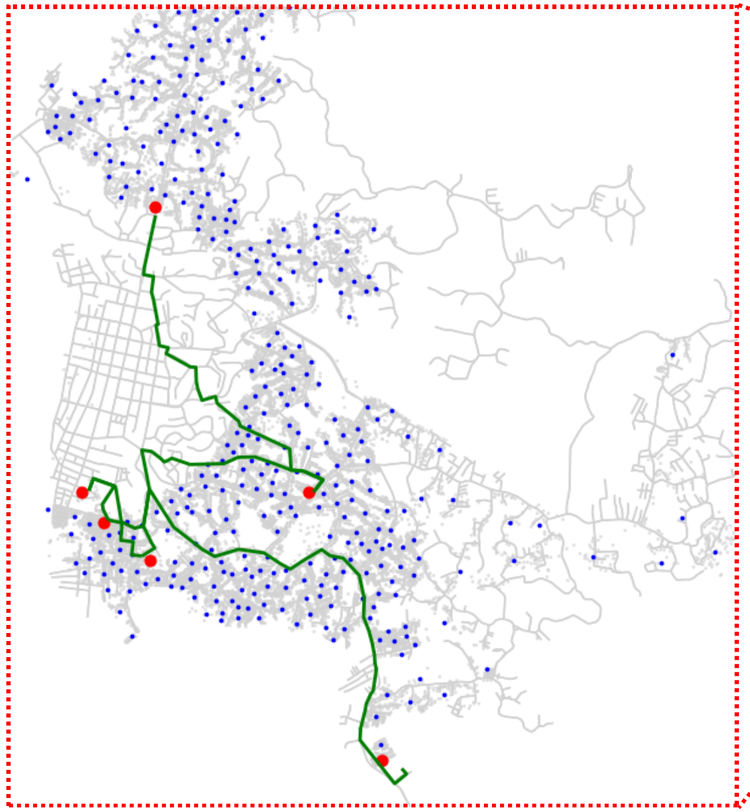
11 SUSTAINABLE CITIES AND COMMUNITIES

6 CLEAN WATER AND SANITATION

Quibdó



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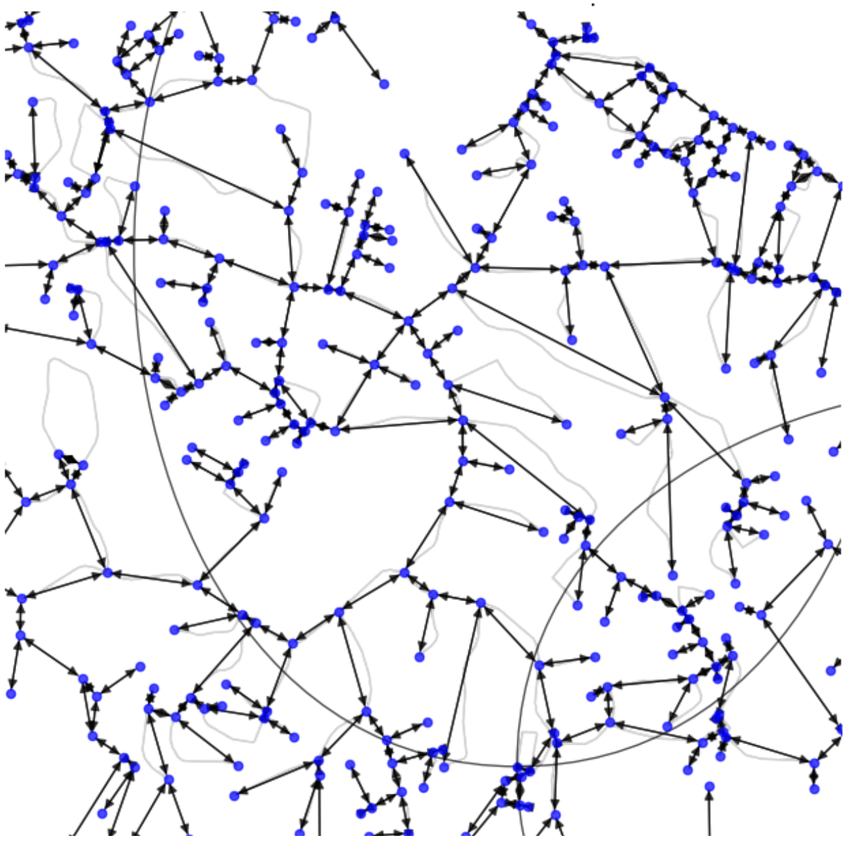

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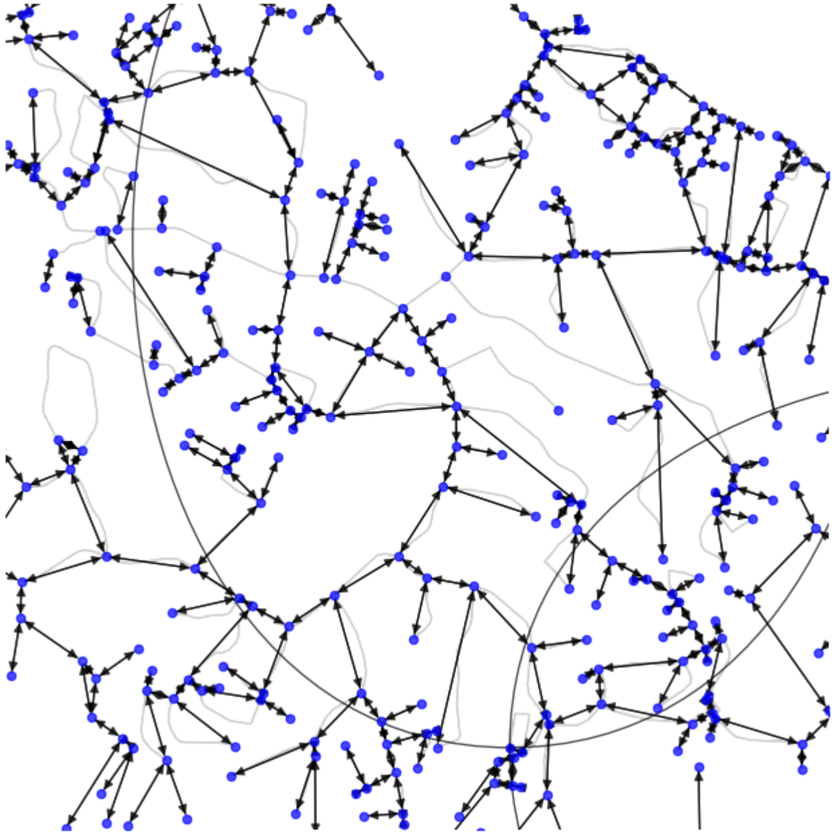

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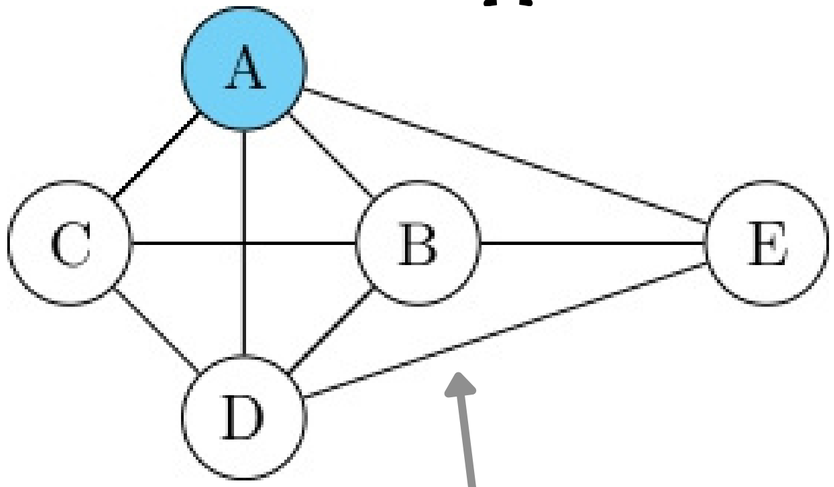

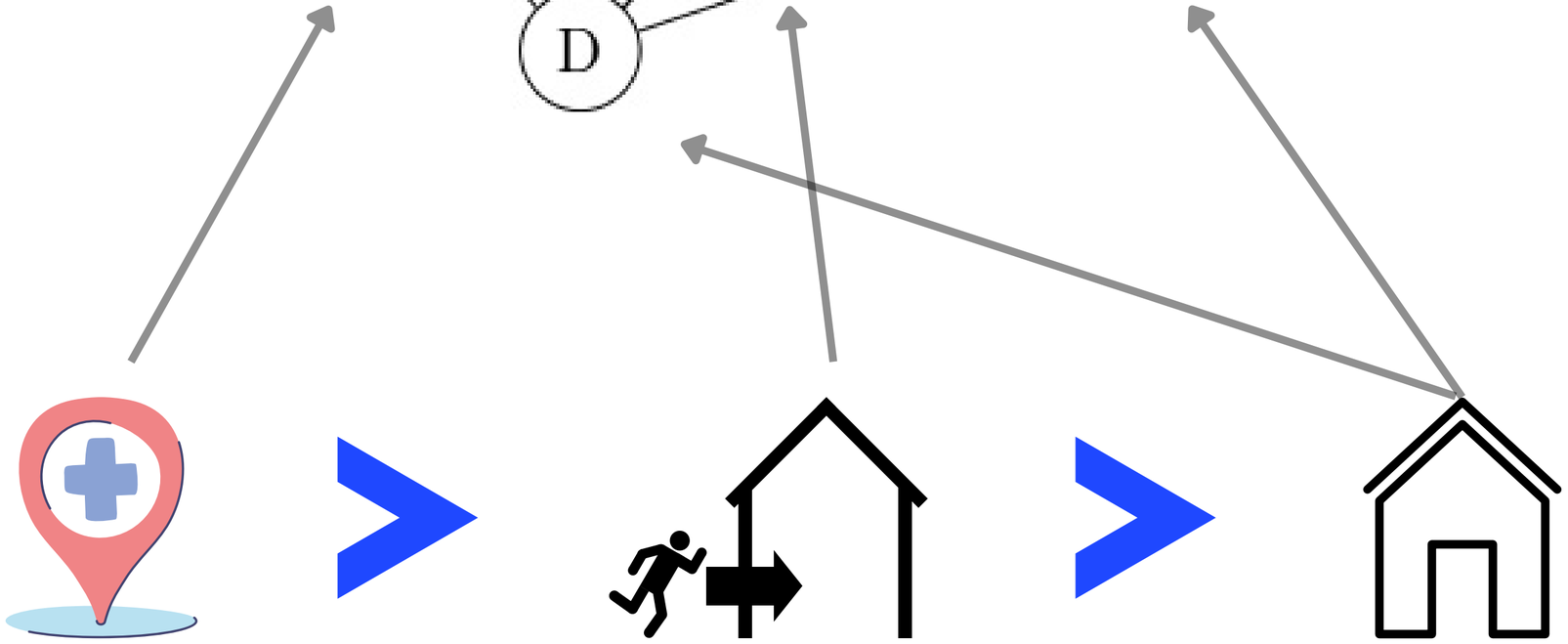

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Why quantum?

- Quantum algorithms like QAOA are designed to **speed up** the calculation of an optimum route in **NP hard problems**.
- In a catastrophe, the difference between 10 minutes and 2 hours can mean the difference between life and death.
- QAOA (Quantum Approximate Optimization Algorithm)

Solving the Traveling Salesman Problem via Different Quantum Computing Architectures

Venkat Padmasola, Zhaotong Li, Rupak Chatterjee, Wesley Dyk

We study the application of emerging photonic and quantum computing architectures to solving the Traveling Salesman Problem (TSP), a well-known NP-hard optimization problem. We investigate several approaches: Simulated Annealing (SA), Quadratic Unconstrained Binary Optimization (QUBO-Ising) methods implemented on quantum annealers and Optical Coherent Ising Machines, as well as the Quantum Approximate Optimization Algorithm (QAOA) and the Quantum Phase Estimation (QPE) algorithm on gate-based quantum computers. QAOA and QPE were tested on the IBM Quantum platform. The QUBO-Ising method was explored using the D-Wave quantum annealer, which operates on superconducting Josephson junctions, and the Quantum Computing Inc (QCi) Dirac-1 entropy quantum optimization machine. Gate-based quantum computers demonstrated accurate results for small TSP instances in simulation. However, real quantum devices are hindered by noise and limited scalability. Circuit complexity grows with problem size, restricting performance to TSP instances with a maximum of 6 nodes. In contrast, Ising-based architectures show improved scalability for larger problem sizes. SQUID-based Ising machines can handle TSP instances with up to 12 nodes, while entropy computing implemented in hybrid optoelectronic components extend this capability to 18 nodes. Nevertheless, the solutions tend to be suboptimal due to hardware limitations and challenges in achieving ground state convergence as the problem size increases. Despite these limitations, Ising machines demonstrate significant time advantages over classical methods, making them a promising candidate for solving larger-scale TSPs efficiently.

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Our first approach: QAOA

$$
\begin{aligned}
H \;=\; & \lambda_1 \sum_{t=1}^{T} \Big(\sum_{i=1}^{n} x_{i,t} - 1 \Big)^2 && \text{(una visita por posición)} \\
& + \lambda_2 \sum_{i=1}^{n} \Big(\sum_{t=1}^{T} x_{i,t} - v_i \Big)^2 && \text{(coherencia visita–posición)} \\
& + \lambda_3 \sum_{t=1}^{T-1} \sum_{i=0}^{n} \sum_{j=0}^{n} D_{ij}\, x_{i,t}\, x_{j,t+1} && \text{(distancia/tiempo)} \\
& + \lambda_4 \Big(\sum_{i=1}^{n} a_i - C \Big)^2 && \text{(capacidad del camión)} \\
& + \lambda_5 \sum_{i=1}^{n} \sum_{b=0}^{B-1} q_{i,b}\,(1 - v_i) && \text{(no entregar si no visitas)} \\
& - \gamma \sum_{i=1}^{n} w_i\, a_i && \text{(recompensa por impacto social)}
\end{aligned}
$$

Asign to each node n qubits

The number of qubits scale as n^2

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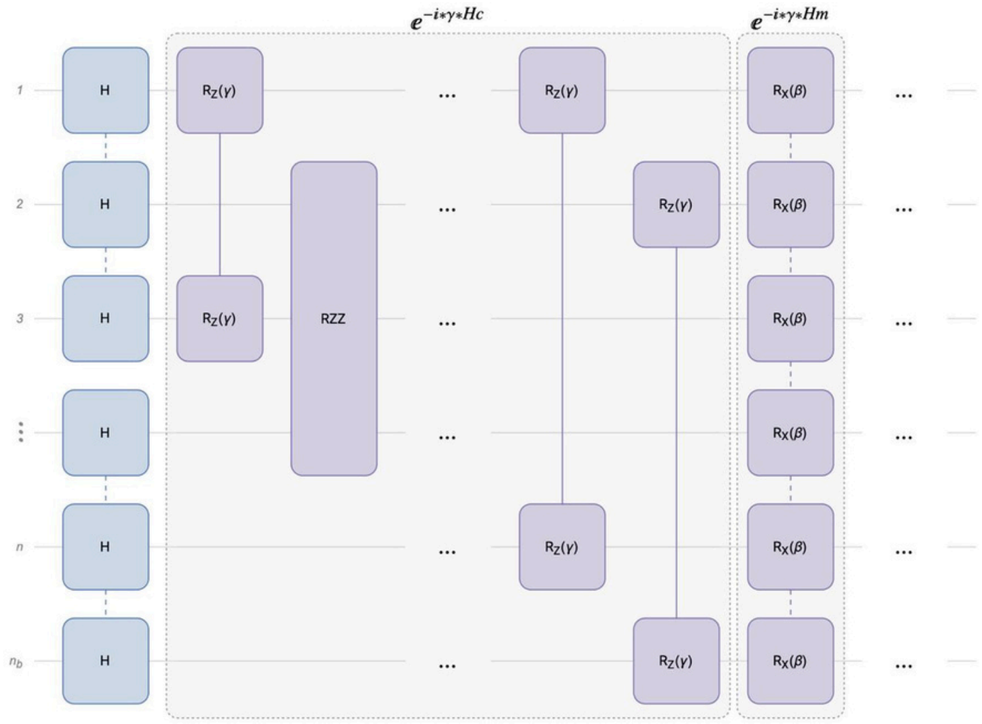
The solution... *iterative* QAOA



The cost function

$$\lambda_1 \sum_{i<j}^{n} D_{i,j} x_i x_j \text{ (distance and position)}$$

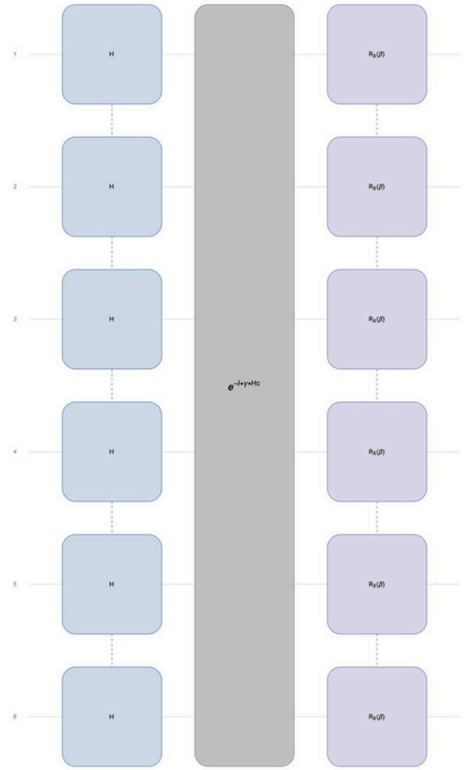
$$\lambda_2 (\sum_{i}^{n} a_i - C)^2 \text{ (transport capacity)}$$

$$-\gamma \sum_{i}^{n} w_i a_i \text{ (social impact)}$$

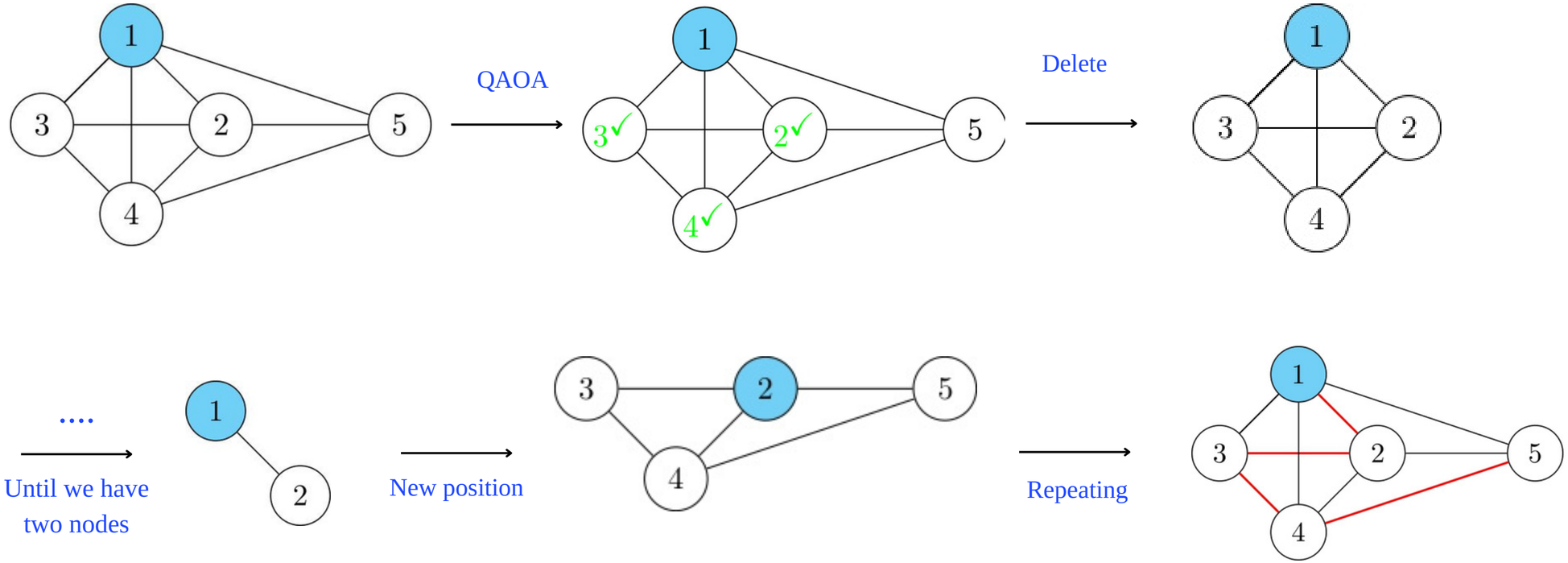
Which will be mapped to…

$$f = \sum_{i<j}^{n} D_{i,j} x_i x_j + \lambda_2 (\sum_{i}^{n} a_i - C)^2 - \gamma \sum_{i}^{n} w_i a_i \rightarrow e^{-i\gamma H}$$

$$f \mapsto H$$

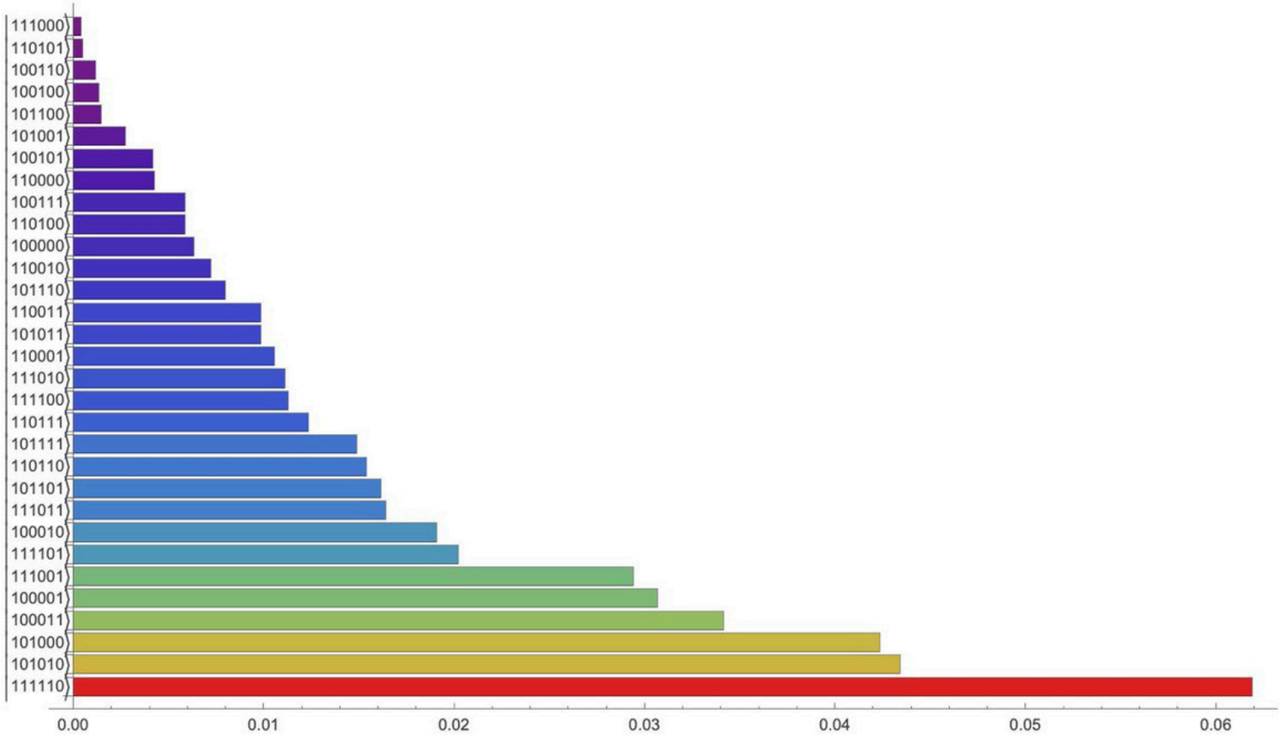


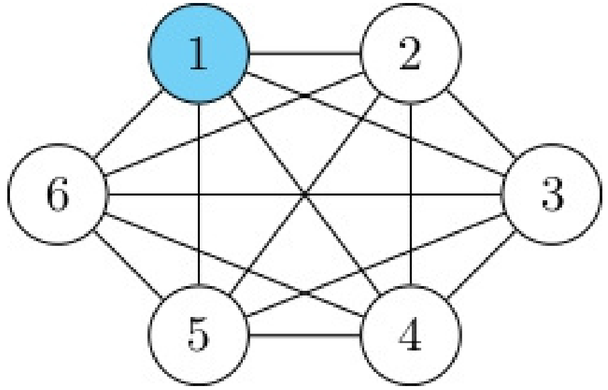
How does this algorithm work on the graph?



Now the number of qubits scale as n

The experiment





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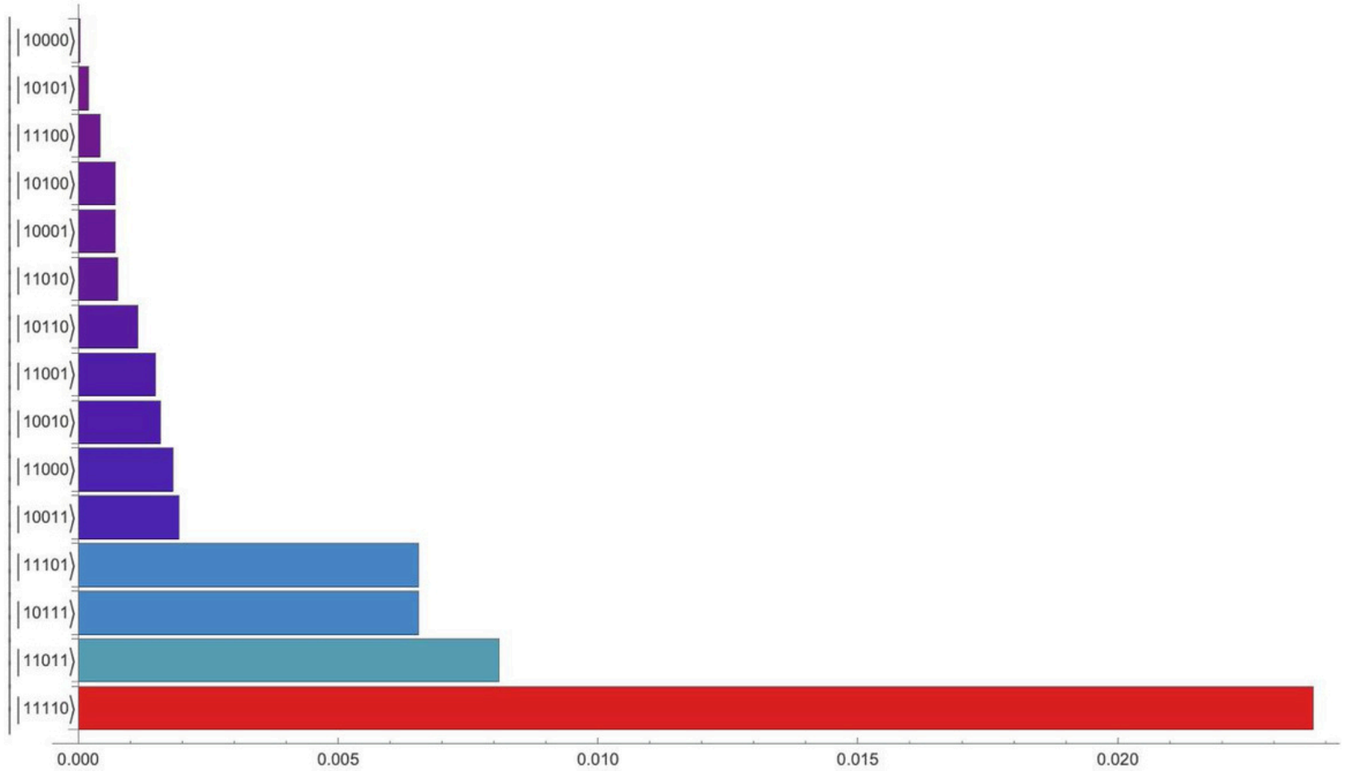

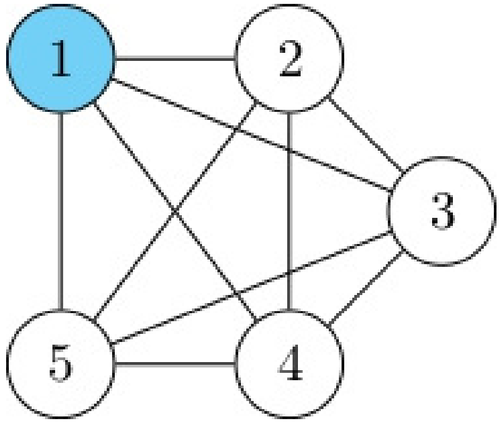

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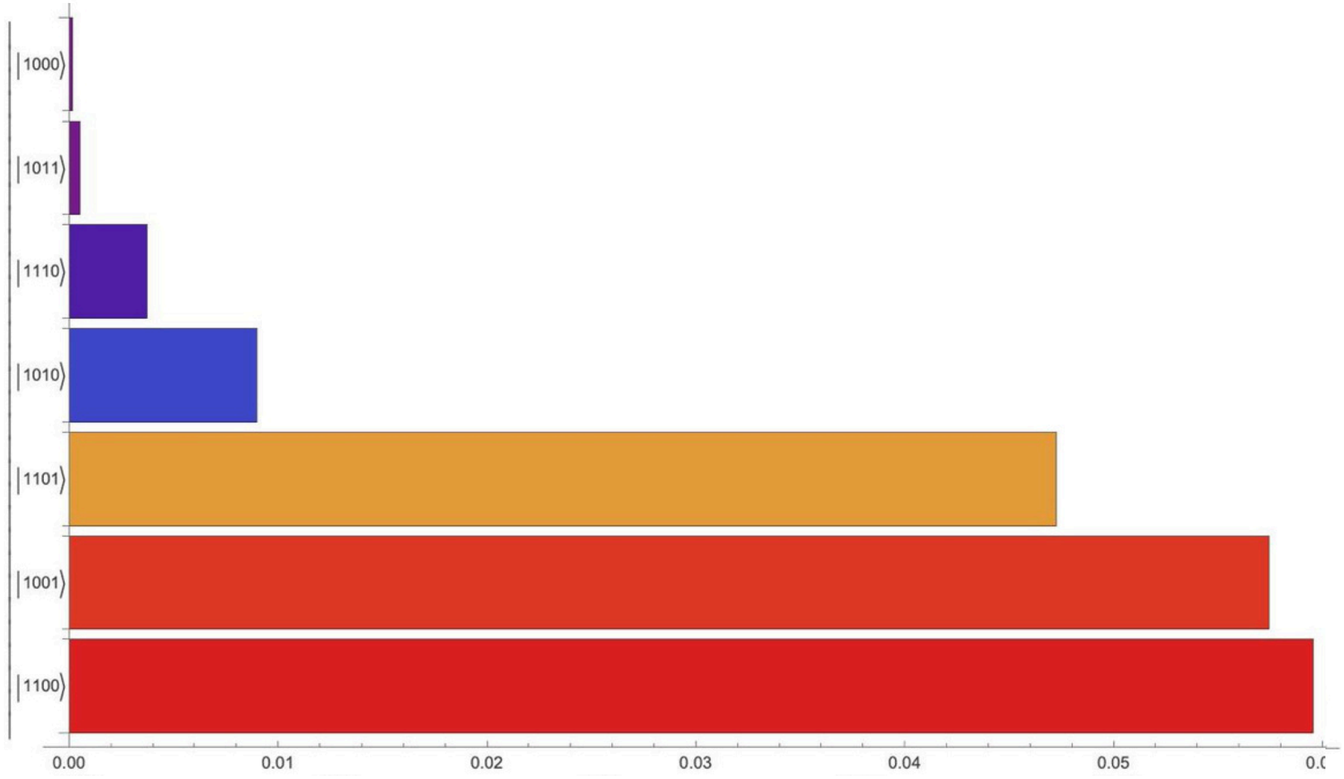

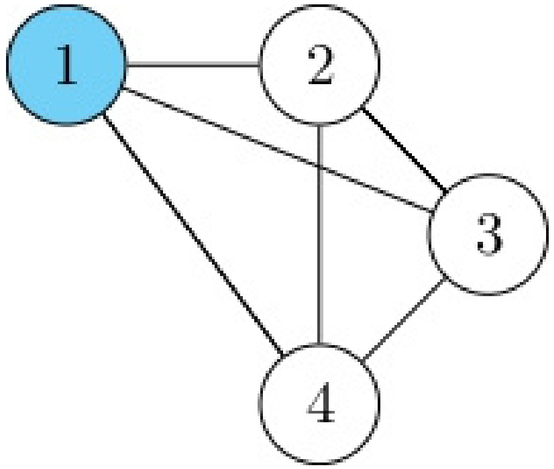

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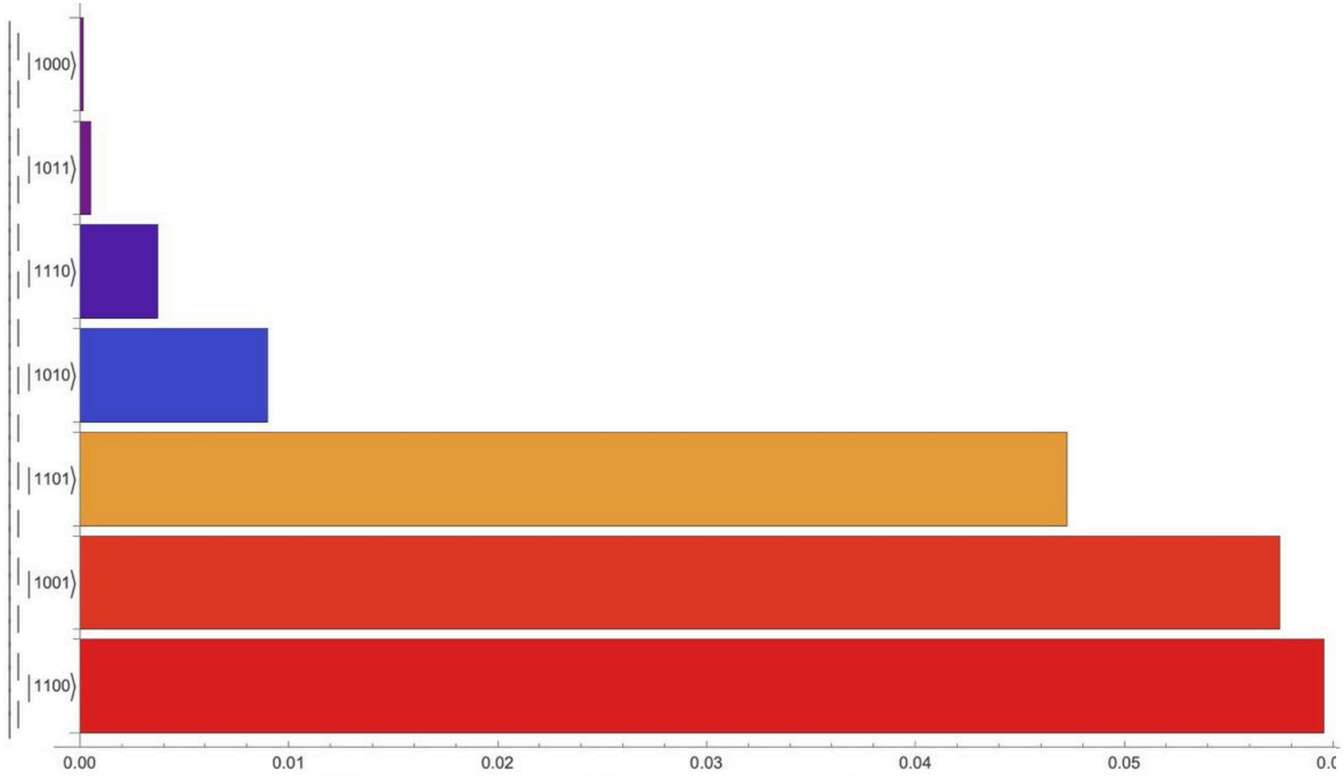

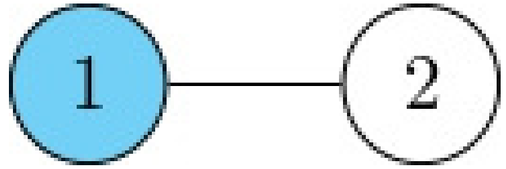

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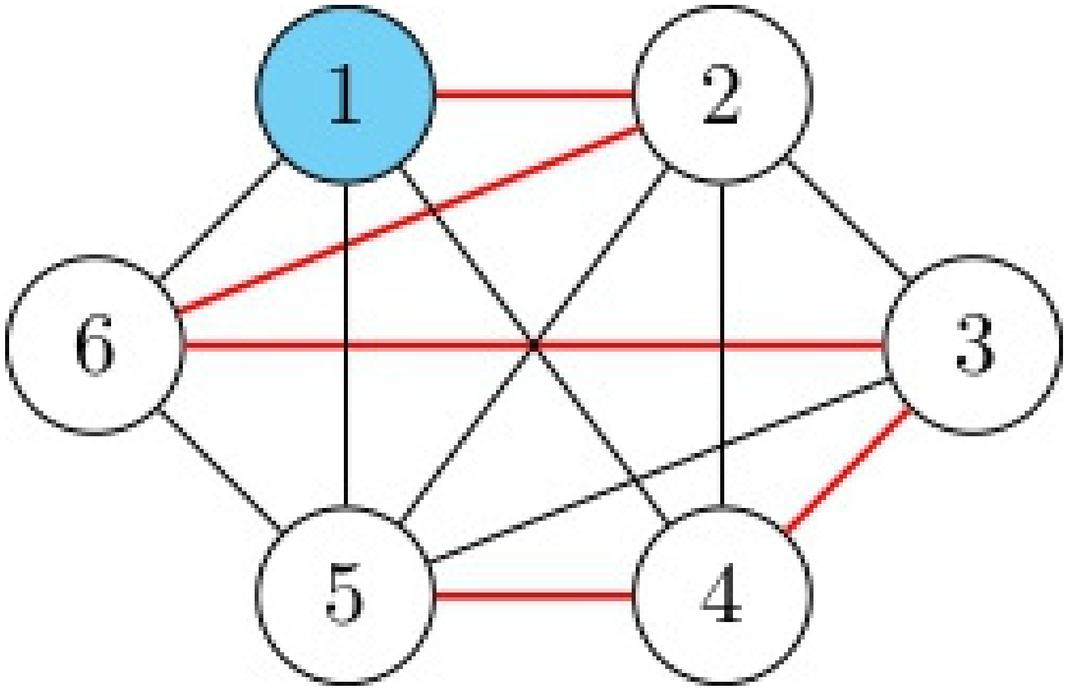

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The DANA weather phenomenon in Spain during September 2024

- Accumulated extreme rainfall
- Loss of life and very significant damage to infrastructure, homes, farms, and communication systems; destruction or damage to sanitation networks and reservoirs; breaks in water pipes affecting the water supply.

Wildfires in Greece in 2021

- It triggered hundreds of simultaneous wildfires in various regions.
- The entire national fire department was mobilized.
- The various simultaneous fires created bottlenecks.

Turkey earthquakes 2023

- Serious consequences in several provinces of Türkiye.
- Enormous damage to buildings and infrastructure.
- Mass displacement of populations.
- Thousands of homes destroyed and tens of thousands of people evacuated.

Thank you so much