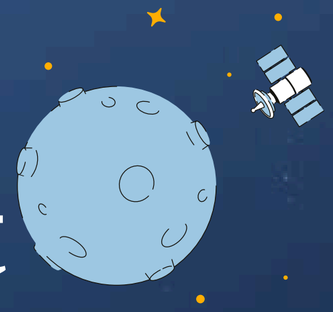
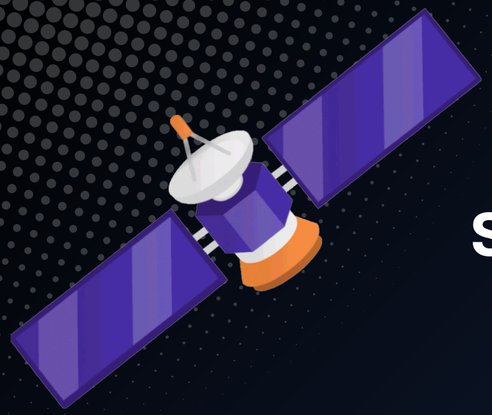
QAOA Based Energy Efficient Satellite Task Sheduling Under Orbital Visibility Constraints



Shreya Palase
(Quantum computing)

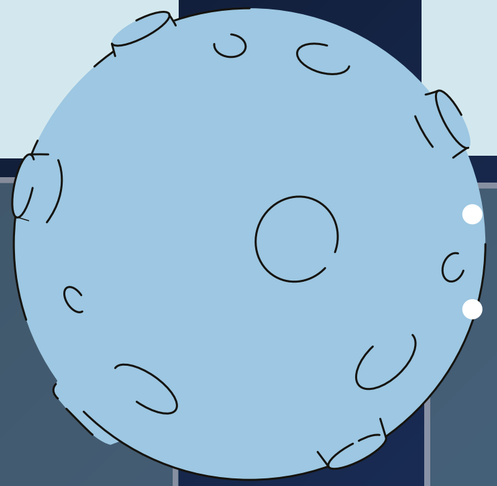
Introduction:



Satellite Task Sheduling is a critical problem in space mission:

Satellite perform tasks like:

- Earth Observation
- Data transmission
- Imaging



These Task Must be:

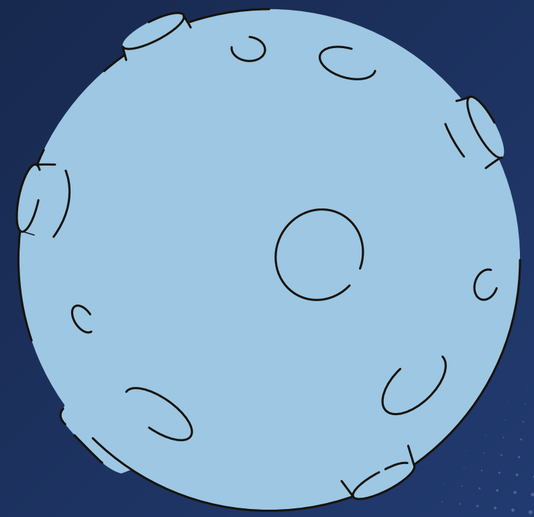
- Energy Efficient
- Executed within limited visibility windows

Efficient scheduling improves mission life-time and performance

Problem Statement

Traditional Scheduling methods face challenges:

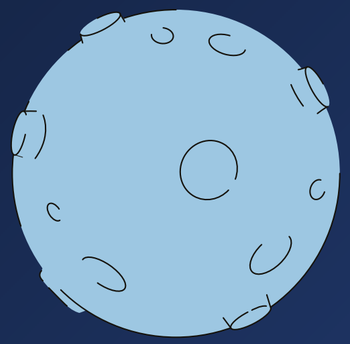
- Limited Onboard Energy
- Conflicting task priorities
- Orbital visibility constraints
- Large- scale optimization complexity



Classical algorithms struggle with:

- Scalability
- Optimal energy usage

Orbital Visibility Constraint



What is orbital Visibility?

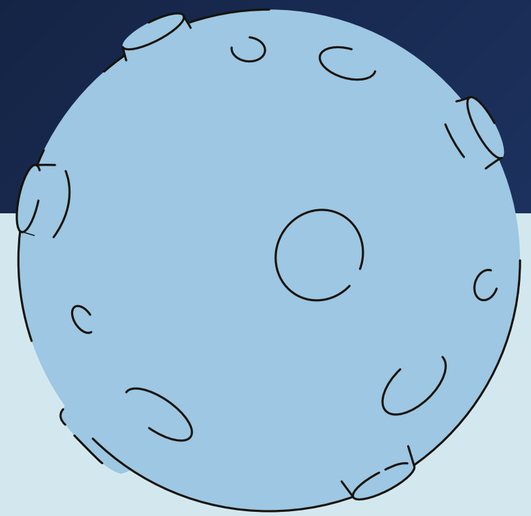
A satellite can perform a task only when the target is visible.

Visibility Depend on :

- satellite orbit
- Earth rotation
- Ground station position

Tasks Must be Scheduled within specific time windows

Energy Efficiency in Satellite



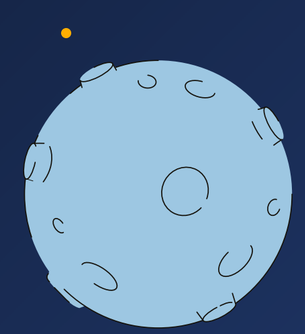
Energy consumption occurs due to:

- Sensor Operation
- Data Processing
- Communication
- Satellite maneuvering

Goal :

Minimize total energy while completing maximum tasks

Why Quantum Optimization?

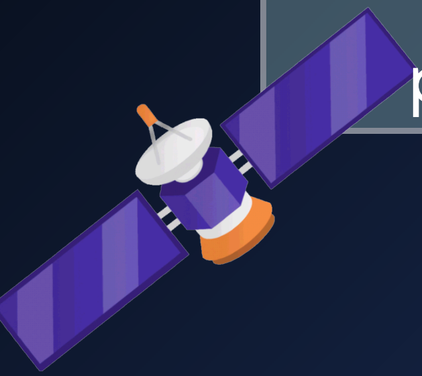


Classical Optimization Struggle with

- Combinatorial explosion
- NP-Hard scheduling problems

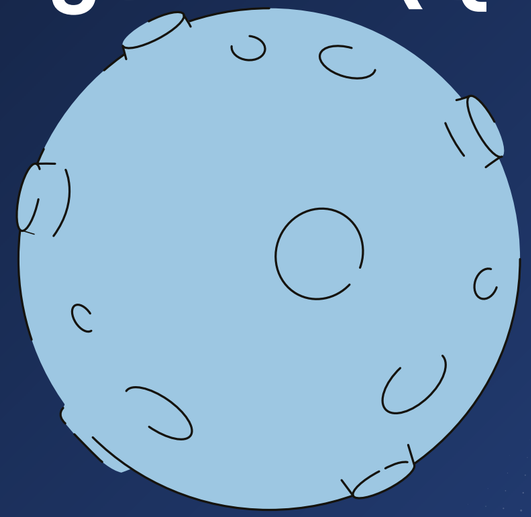
Quantum offers new optimization capabilities

- Explore Multiple solution Simultaneously
- Better suited for complex constraints



Introduction to QAOA

Quantum Approximation Optimization Algorithm(QAOA)



- Hybrid Quantum-classical algorithm
- Designed for Combinatorial optimization
- Uses:

1. Quantum circuit
2. Classical parameter turning

Ideal for scheduling and resource allocation problems

QAOA-Based Scheduling Approach

Step -by -Step process:

1. Model Scheduling as an optimization problem
2. Encode tasks as quantum states
3. Define:
    - Cost function(energy usage)
    - Constraints(visibility,task conflicts)
4. Apply QAOA to near find optimal schedules.

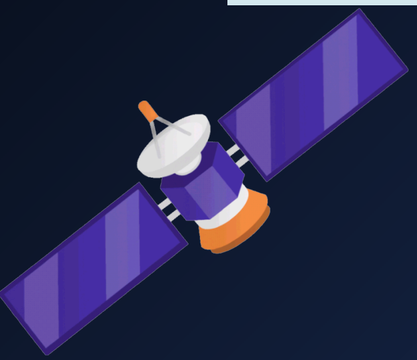
Mathematical Formulation

Objective

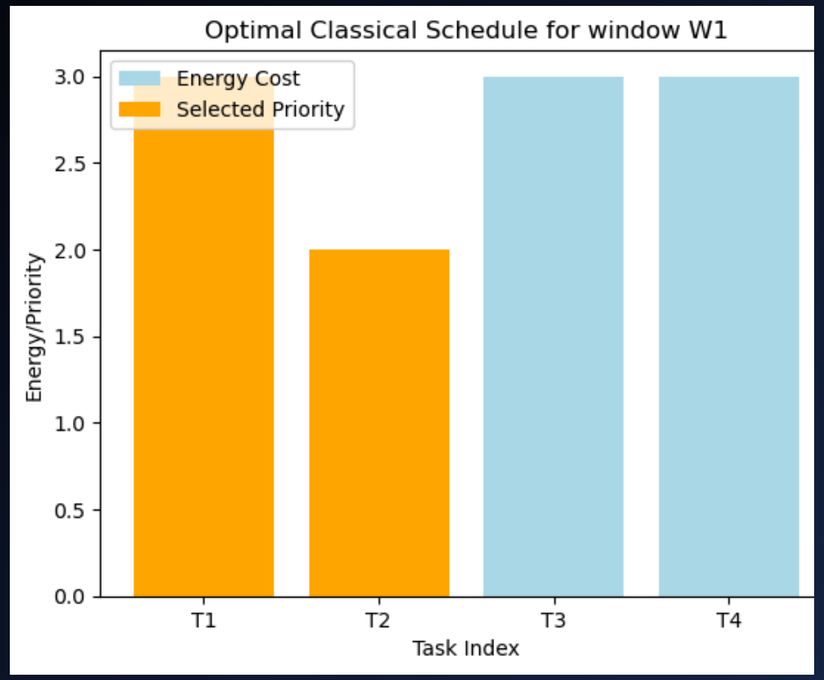
- Minimize Total Energy Cost

Constraints

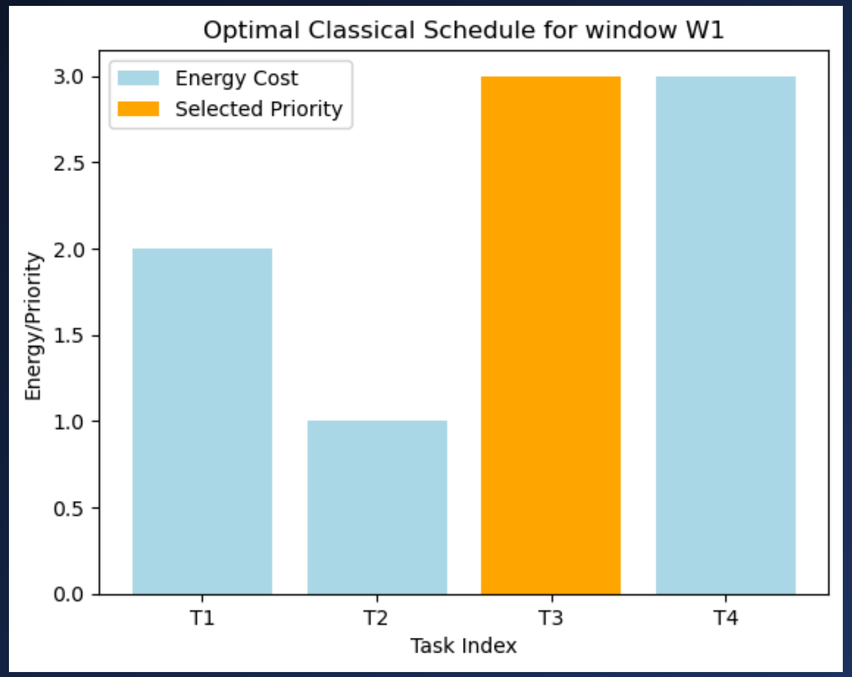
- Each task schedulted once
- Task only within visibility window
- No overlapping conflicting tasks



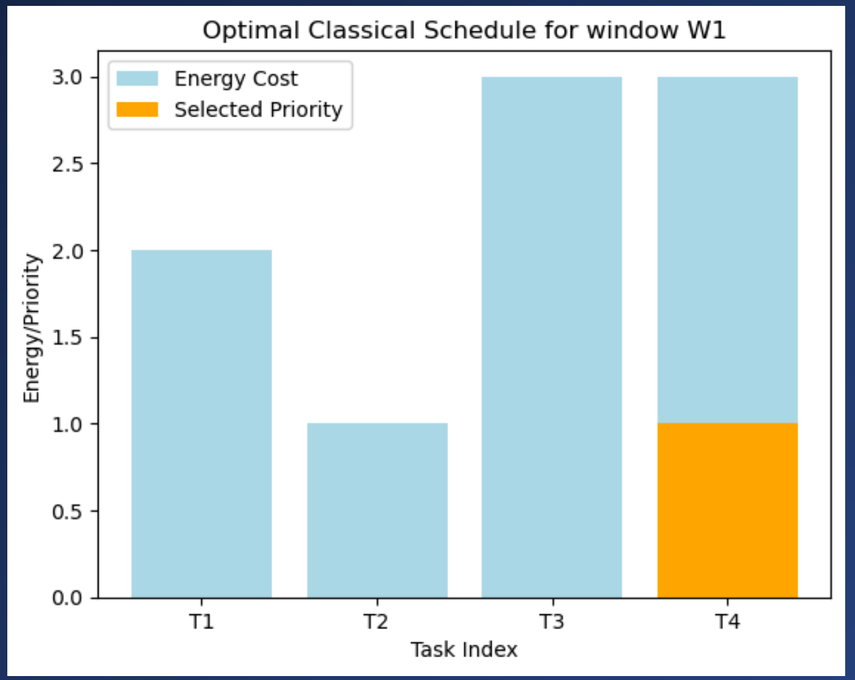
Classical Output



W1 window for T1 & T2

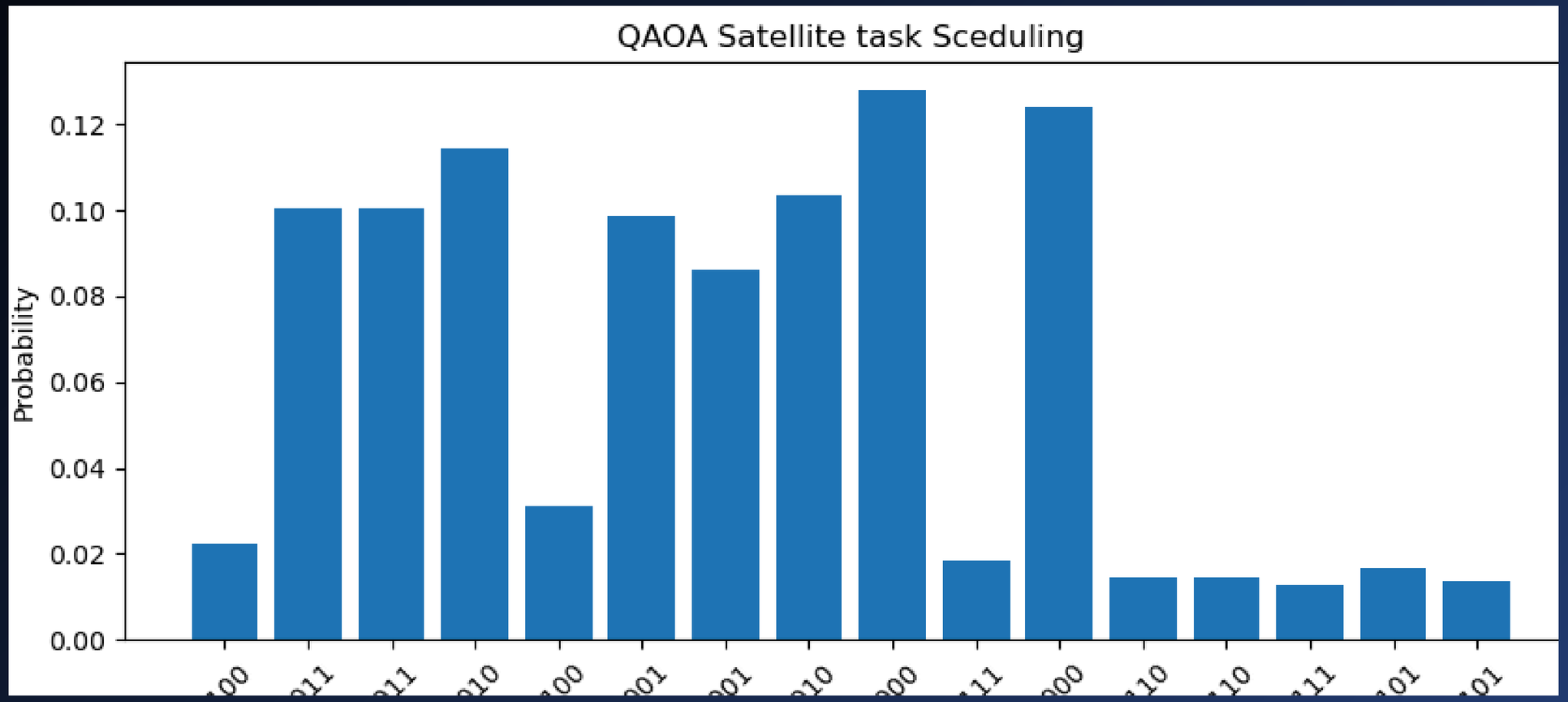


W2 Window For Task T3



W3 window for Task T4

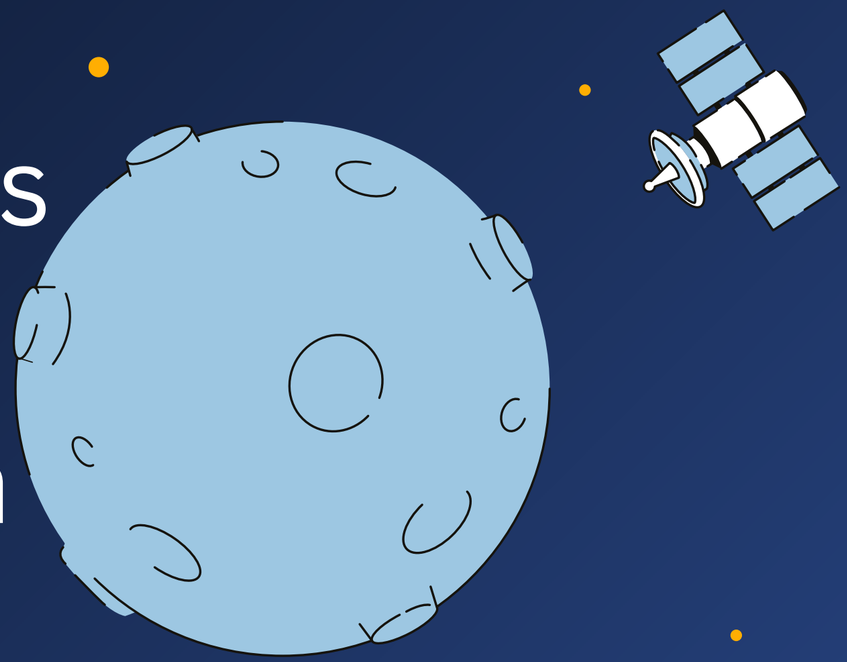
Quantum QAOA Result



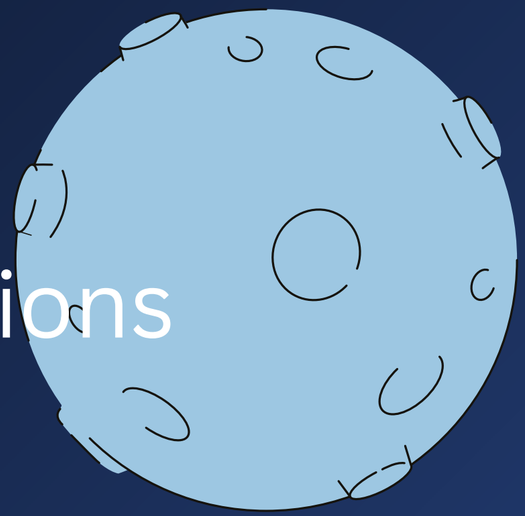
High probability for T4

Advantages of QAOA-Based Scheduling

- Better Energy optimization
- Handles complex constraints
- Scalable for large task sets
- Suitable for future Quantum Hardware



Challenges & Limitations



- Current Quantum hardware limitations
- Noise and decoherence
- Hybrid implementation complexity

Still Effective using quantum simulators

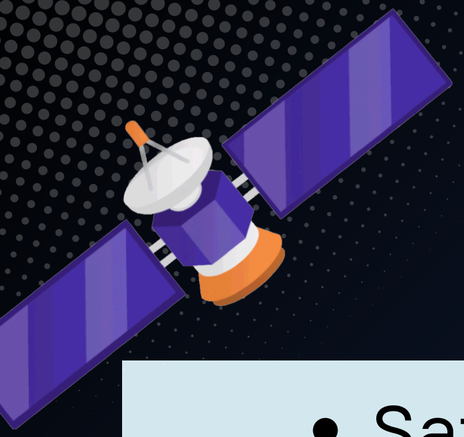
Applications

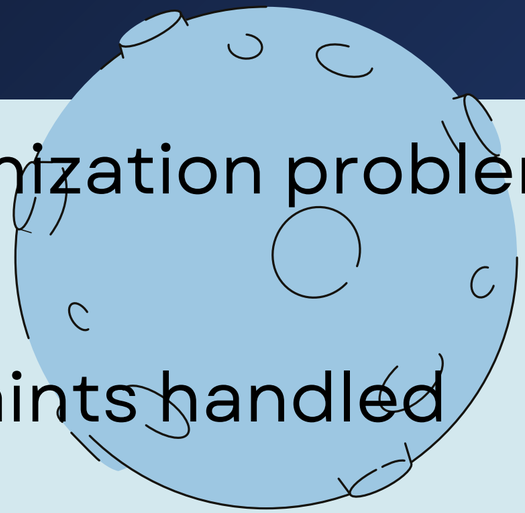
- Earth Observation Satellite
- Remote sensing missions
- Communication satellites
- Autonomous satellite operation

Future Scope

- Multi - satellite scheduling
- Real time adaptive scheduling
- Integration with AI and ML
- Execution on advanced quantum processors

Conclusion





- Satellite scheduling is a complex optimization problem
- QAOA provides an innovative solution
- Energy efficiency and visibility constraints handled effectively
- Promising approch for next-generation space mission