Dispatching Shots Among Multiple Quantum Computers: an Architectural Proposal

Giuseppe Bisicchia[1], Jose García-Alonso[2], Juan M. Murillo[2] and Antonio Brogi[1]

[1]*Service-oriented, Cloud and Fog Computing Group*
Department of Computer Science
University of Pisa, Italy

[2]*Quercus Software Engineering Group*
Dept. of Computer and Telematic Systems Engineering
University of Extremadura, Spain

3rd International Workshop on Quantum Software Engineering and Technology, 20 September 2023


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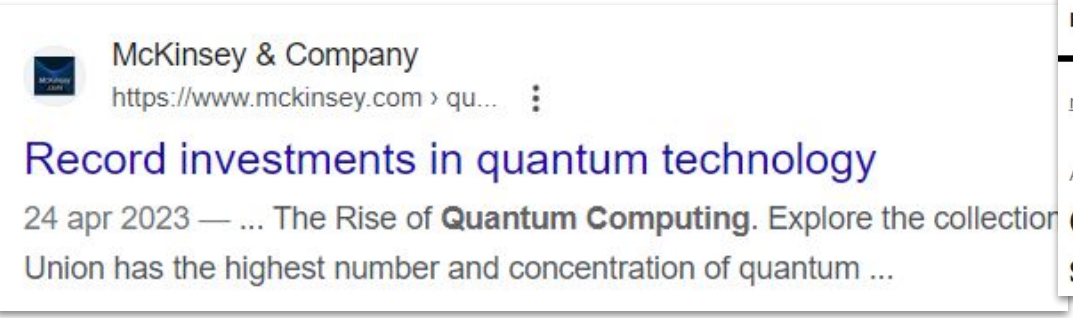
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OQC

ibm_cairo		27	64	2.4K	Online	16	Falcon r5.11	premium	OpenQASM 3
ibm_auckland	Exploratory	27	64	2.4K	Online	1818	Falcon r5.11	premium	OpenQASM 3
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IonQ IonQ	Quantum Computing	Azure Quantum Credits
Microsoft Quantum Computing Microsoft	Quantum Computing	Learn & Develop
Quantinuum Quantinuum	Quantum Computing	Azure Quantum Credits
Rigetti Quantum Rigetti Computing	Quantum Computing	Azure Quantum Credits

Amazon Web Services	SV1	AVAILABLE NOW
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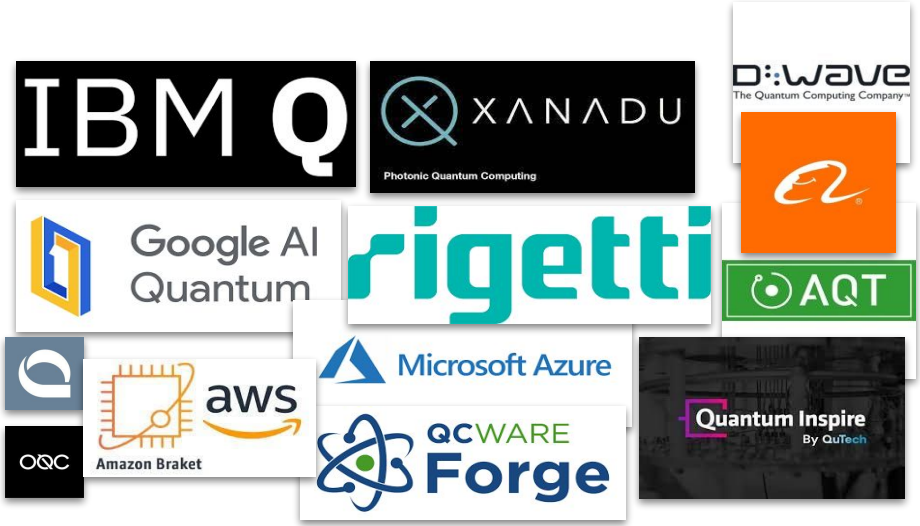
IonQ	Aria 1	02:44:47
Oxford Quantum Circuits	Lucy	00:44:47
QuEra	Aquila	1 day 06:44:47
Rigetti	Aspen-M-3	05:44:47

The Quantum Daily's Guide to Qubit Implementations

THE QUANTUM DAILY
QUANTUM COMPUTING AND BEYOND

Classification	Description	Examples	Qubit lifetime (1)	Gate fidelity (2)	Gate operation time (3)	Connectivity	Scalability	Pros	Cons
Superconducting	Two level system of a superconducting circuit which forms a qubit (a transmon, first developed at Yale)	IBM, Google, Rigetti, Alibaba, Intel, Quantum Circuits	c.50-100µs	c.99.4%	c.10-50ns	Neighbours	Highly scalable (see OQC coaxmon tech)	- Fast gate times - Builds on existing semiconductor industry	- Typically low longevity - Must be kept very cold to work
Ion trap	Single charged ions trapped in magnetic fields. Energy level of its spin comprises the qubits	IonQ; Alpine Quantum Technologies; Honeywell	>1,000s	c.99.9%	c.3-50µs	All-to-all	TBC	- High gate fidelity - Very stable	- Slow operations
Photonics	Qubits made from single particles of light (photons) operating on silicon chips pathways	PsiQuantum, Xanadu	c. 150µs	c. 98.0%	c.1ns	Unknown	Highly scalable (see Psi Quantum)	- Highly scalable - Utilises existing SC industry infrastructure - No temperature requirements	- Nascent technology - Connectivity to be demonstrated
Neutral atoms	Qubits made from individual atoms (rather than ions which have a charge)	Atom Computing, PASQAL, QuEra	Similar to ion trap	c.95%	TBC	TBC	TBC	- Long qubit coherence times	- Must be kept cold - Nascent
Silicon	Artificial atoms made by adding an electron to a small piece of pure silicon and microwaves control the electrons state	Intel, Silicon Quantum Computing	c. 1-10s	c. 99%	c.1-10ns	Neighbours	Expect high scalability	- Stable - Utilises existing semiconductor industry infrastructure	- Must be kept cold - Nascent
Topological qubits	Qubits made from non-Abelian forms of matter	Microsoft (WIP)	Very high	Very high	Unknown	Unknown	Unknown	- Estimated long lifetime and high fidelities	- Existence to be confirmed

Notes: (1) *Record coherence time for a single qubit position state; (2) Highest reported fidelity for two qubit gate operations; (3) Speed of gate operations*
Sources: Literature review, TQD expert interviews. Special reference to BCG reports, Science Mag and NAE report on quantum computing.
s = seconds
µs = microsecond (10^ -6 seconds)
ns = nanosecond (10^ -9 seconds)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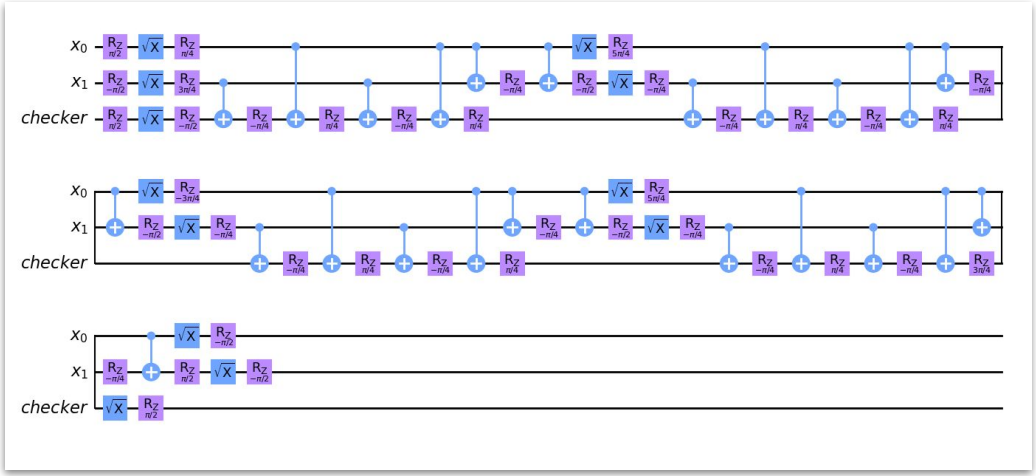
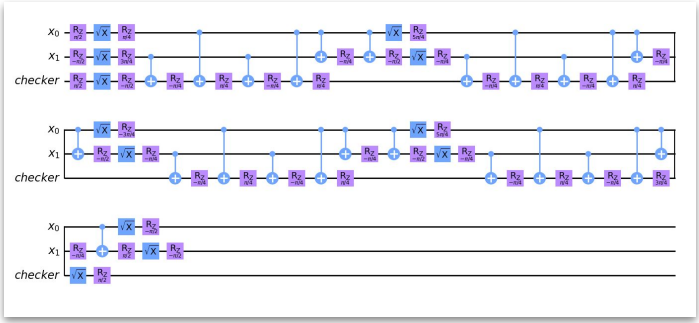


On which Quantum Computer should I run my circuit?



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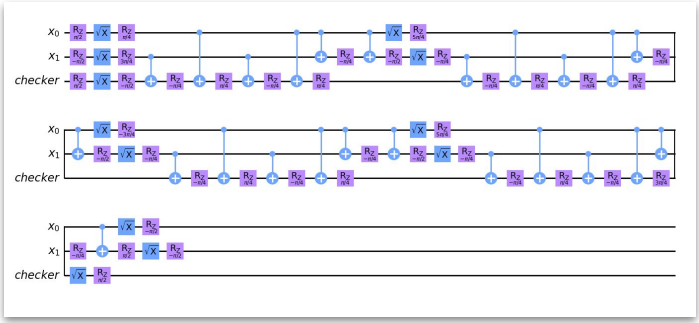

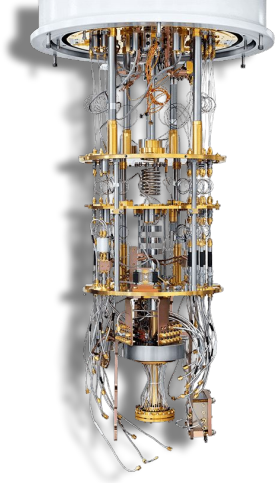

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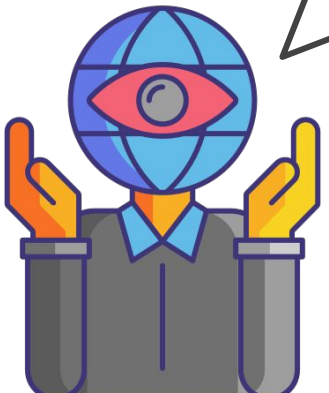
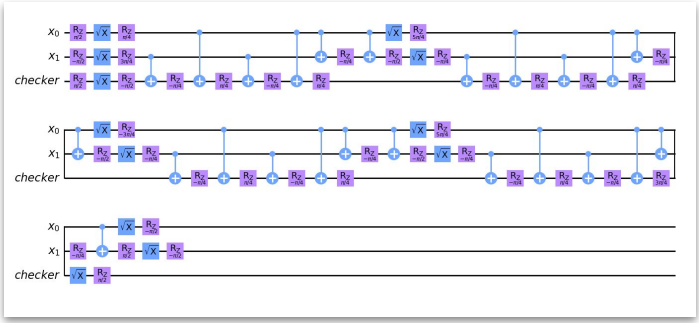
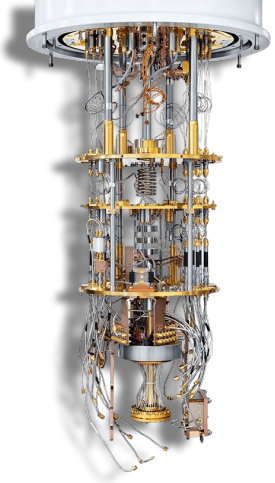
IBM Kyiv







OK, then let's **shoot**!

BUT

What happens if the Quantum Computer becomes **unavailable** while **executing my shots**?

What happens if the Quantum Computer becomes **unavailable** while **executing my shots**?

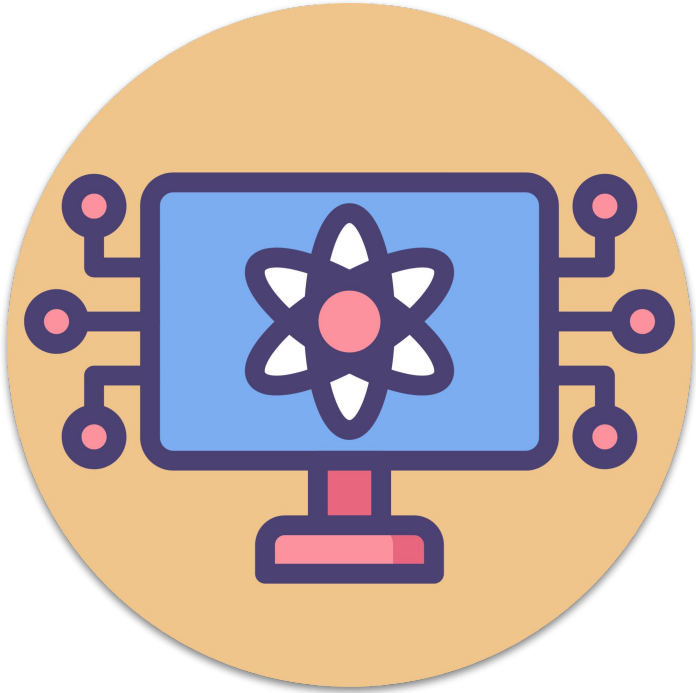
How can I **mediate** between my **cost**, **time** and **accuracy requirements**?

What happens if the Quantum Computer becomes **unavailable** while **executing my shots**?

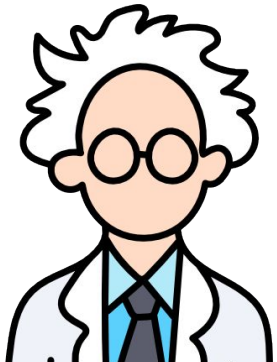
How can I **mediate** between my **cost**, **time** and **accuracy requirements**?

How can I **customise** the Quantum Computer's **decision process**?

OUR PROPOSAL



Let's **distribute** the **shots** among **multiple Quantum Computers**!



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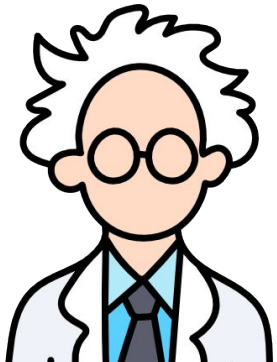
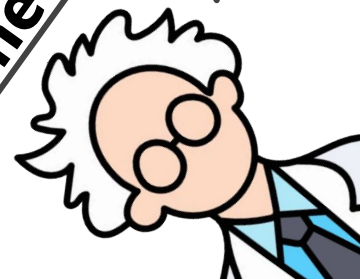
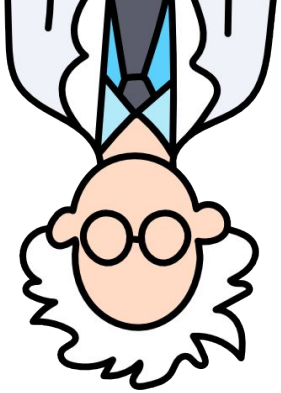


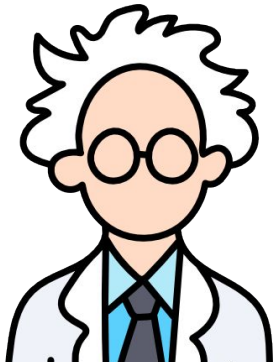
Let's **decouple** the **selection mechanism**!





Let's offer the **partial distributions**!

Let's **distribute** the **shots** among **multiple Quantum Computers**!



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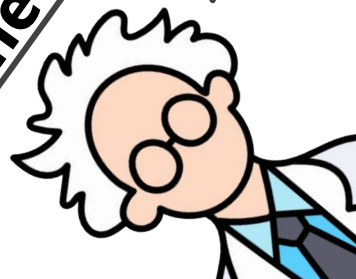
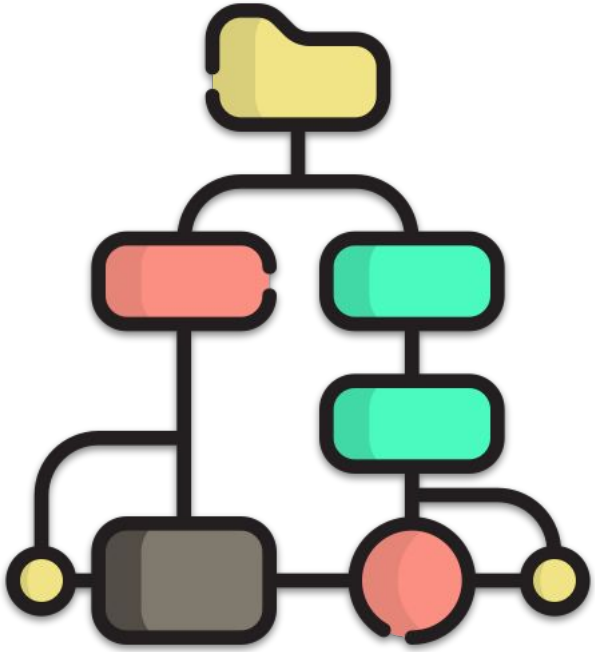
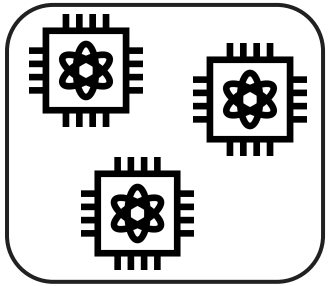
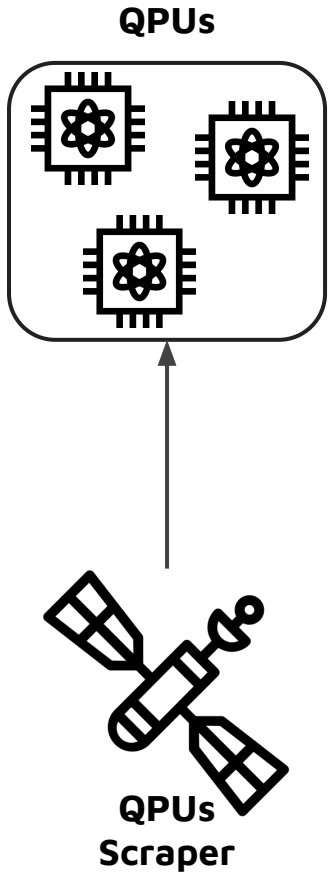


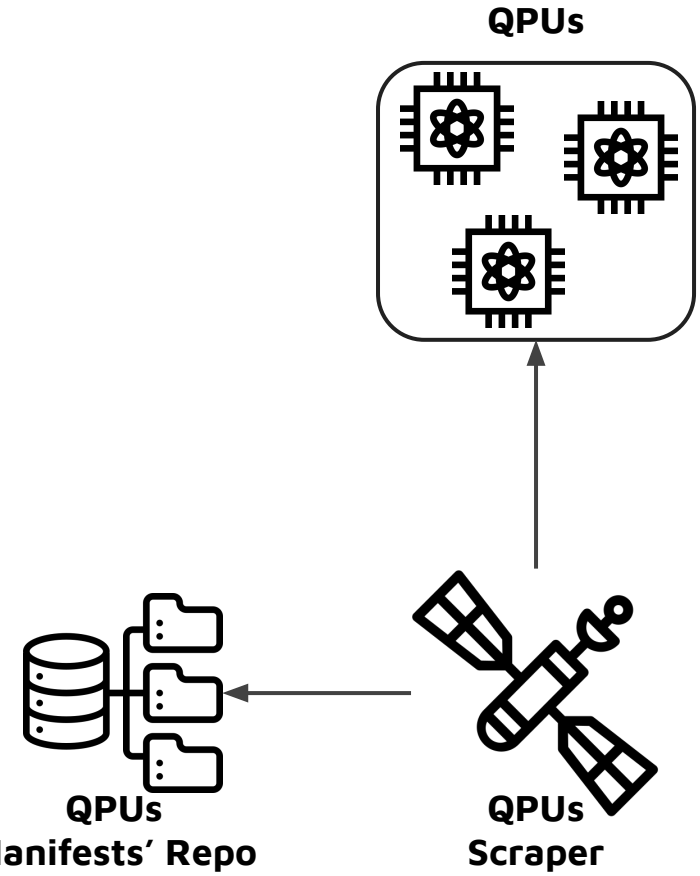
THE ARCHITECTURE



QPUs




QPUs
QPUs
Scraper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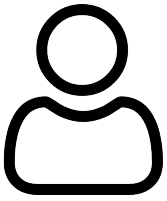

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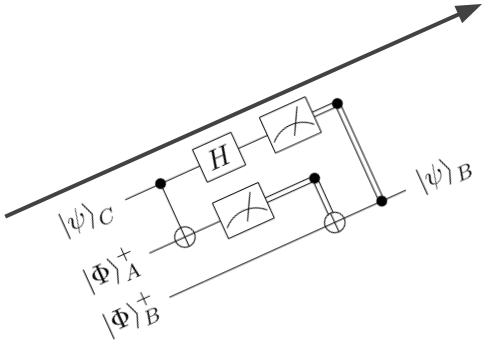

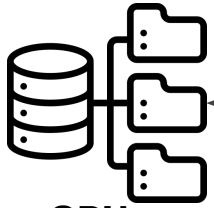

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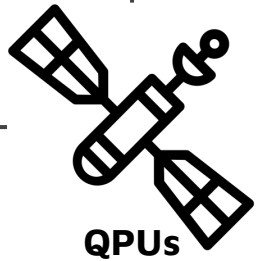

QPUs
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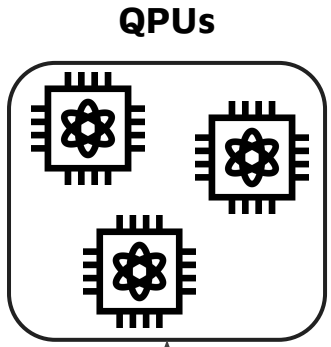
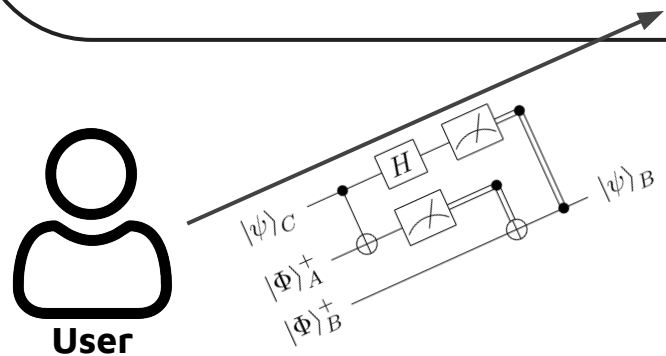


QPUs

Quantum Broker

QPUs



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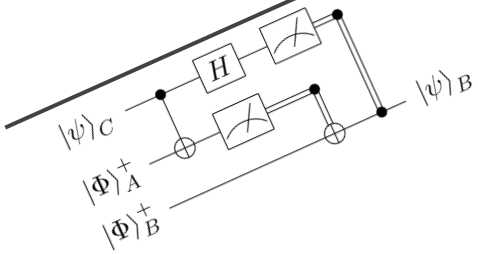
Manifests' Repo

QPUs
Scraper

Quantum Broker

QPUs

Circuit Analyser



User

QPUs Manifests' Repo

QPUs Scraper

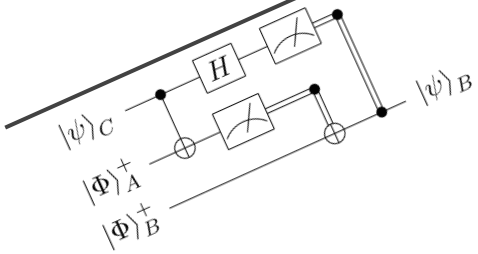
Quantum Broker

Control Plane

Circuit Analyser

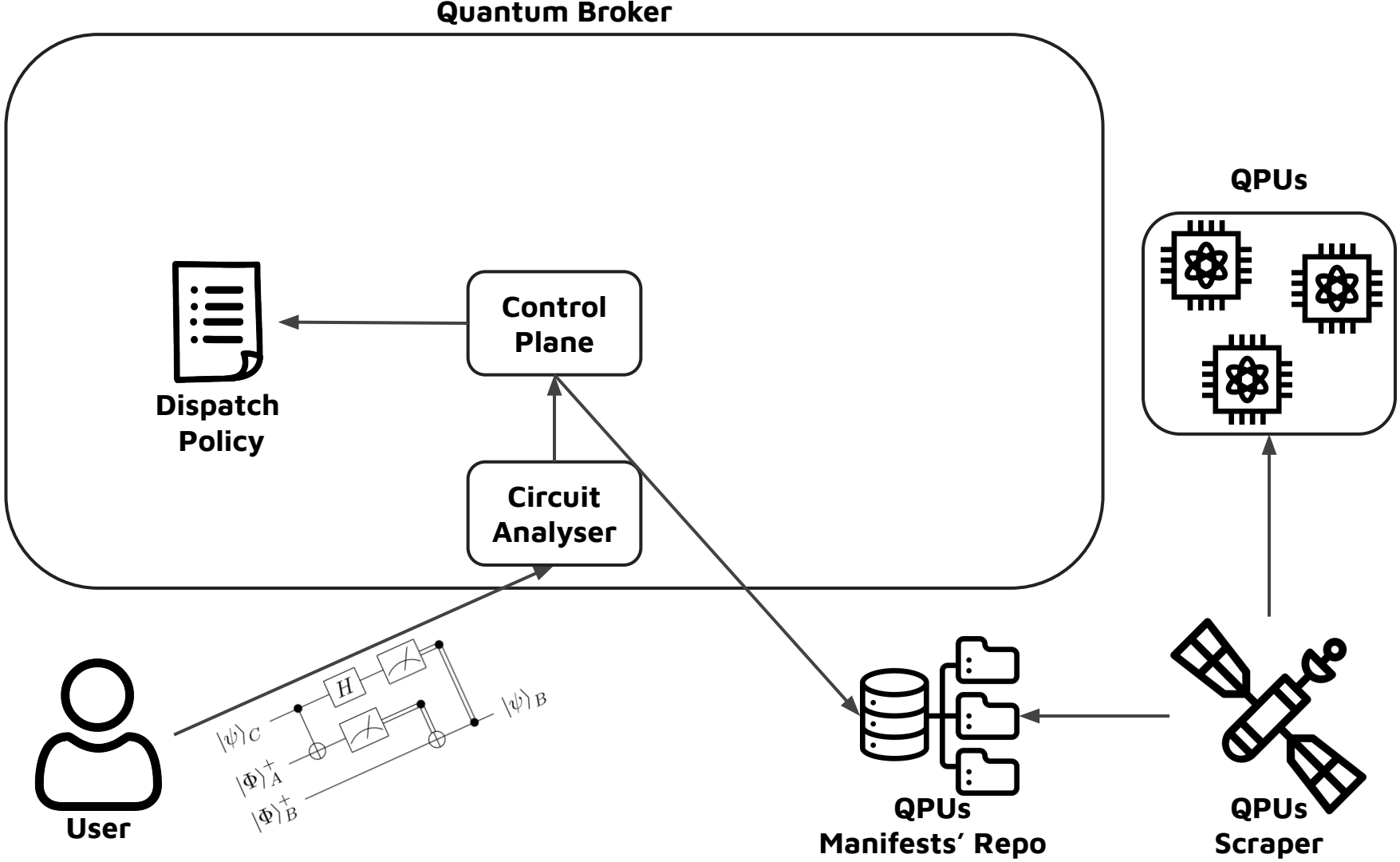
QPUs

User



QPUs Manifests' Repo

QPUs Scraper


Quantum Broker
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Data Plane

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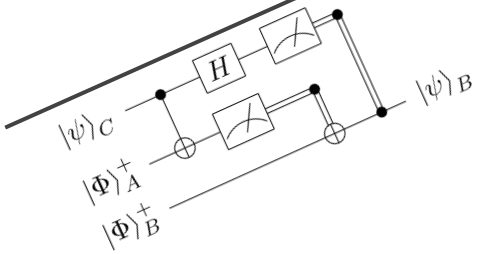

QPUs Manifests' Repo

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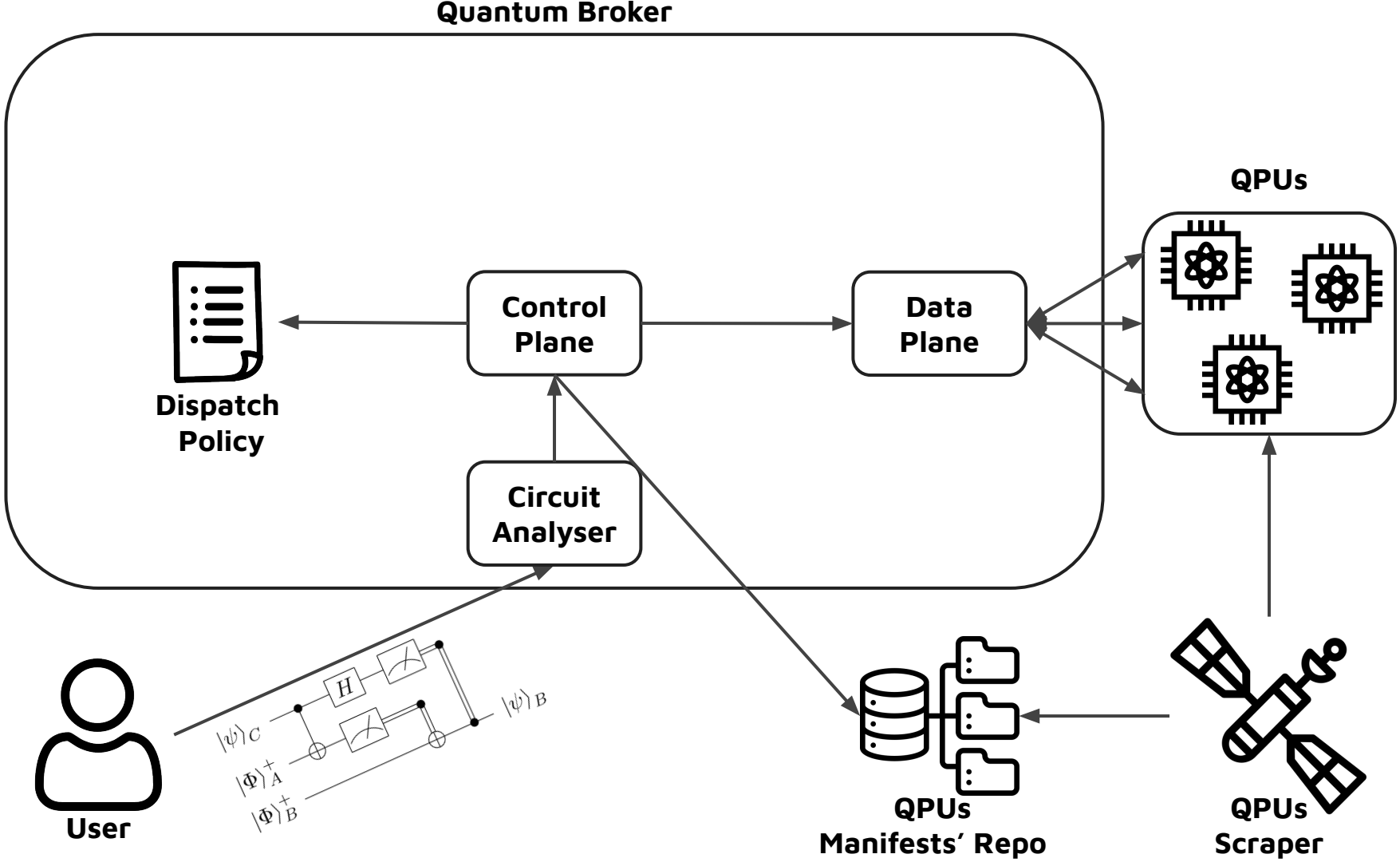
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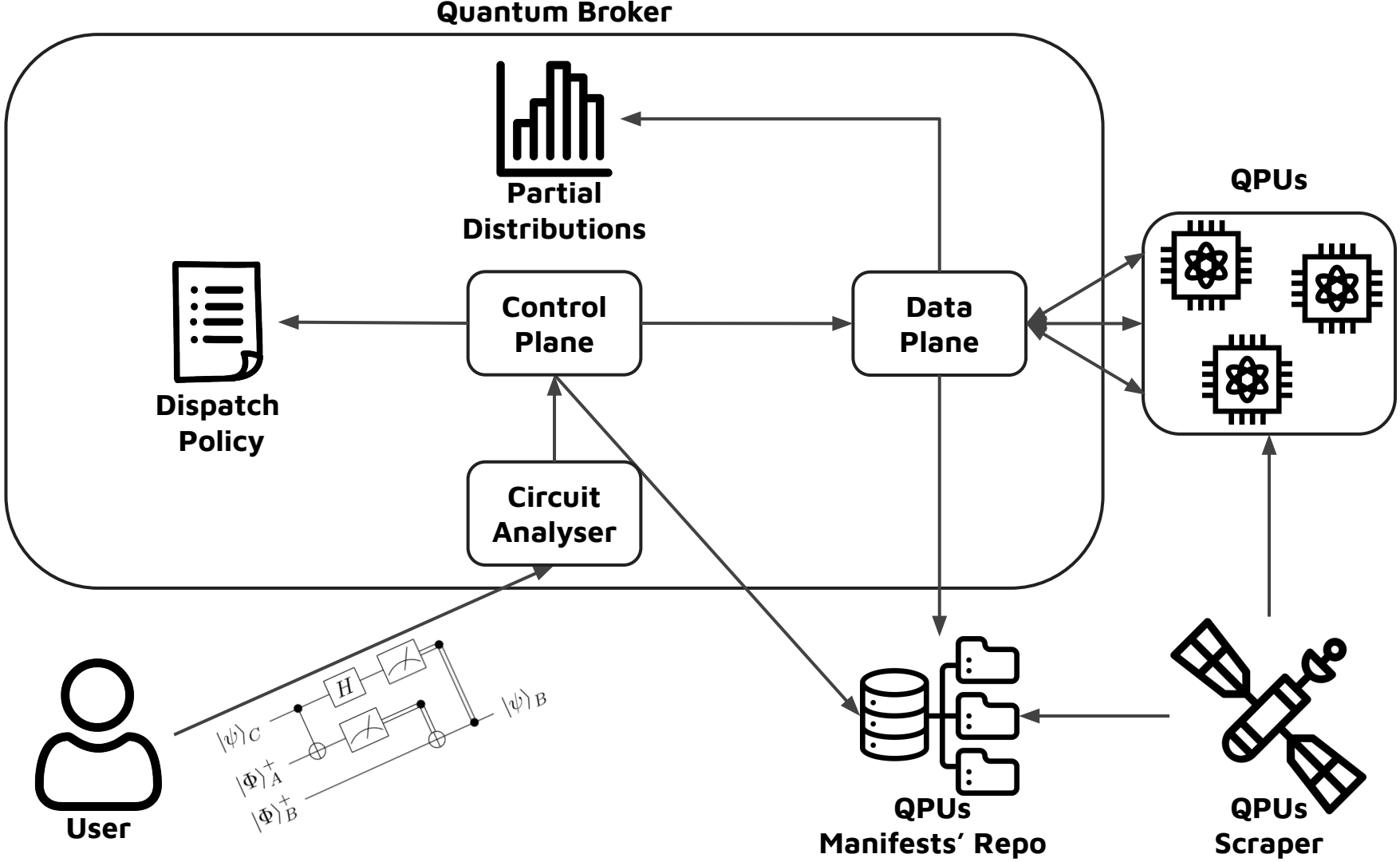
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Partial Distributions
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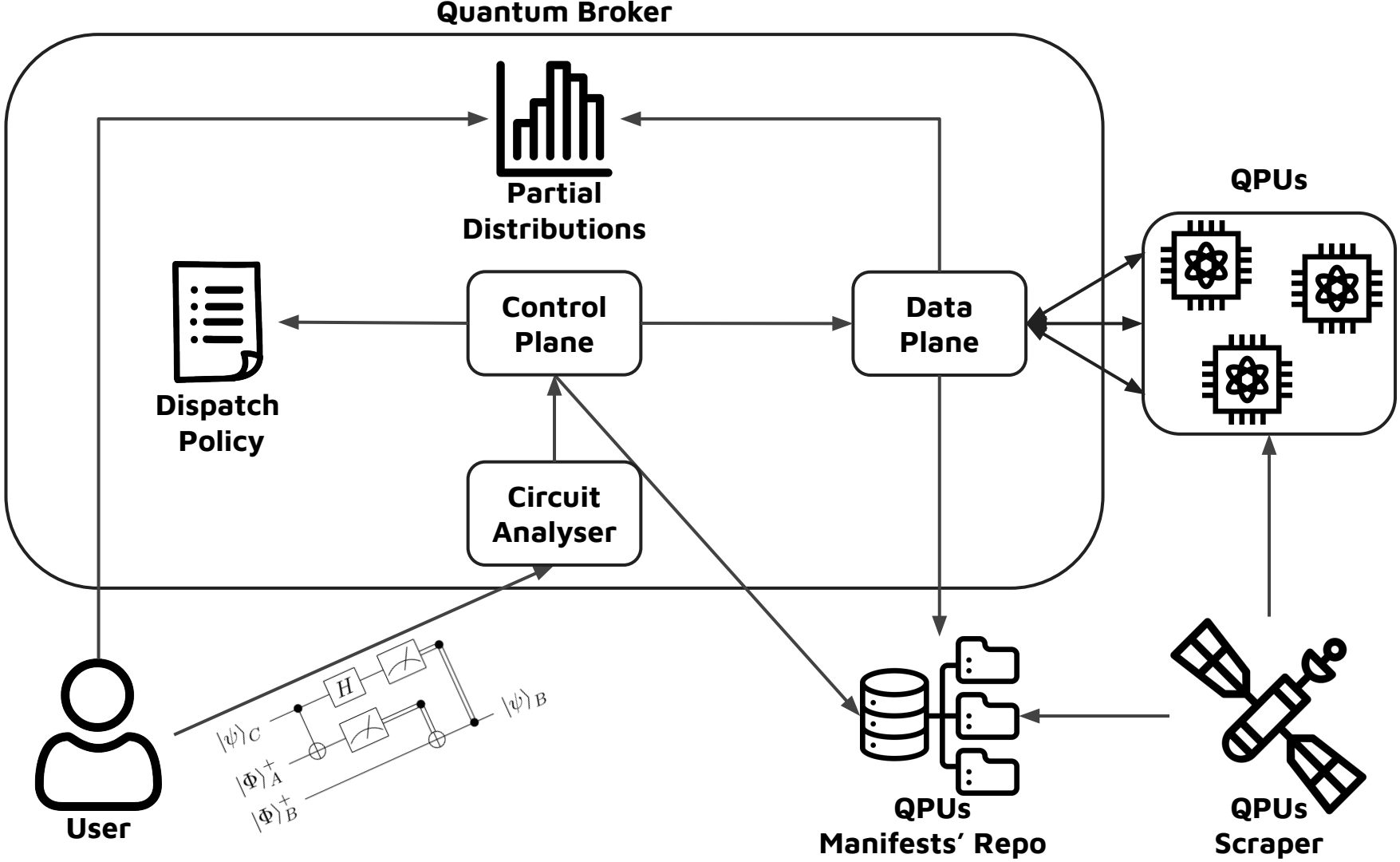
QPUs Scraper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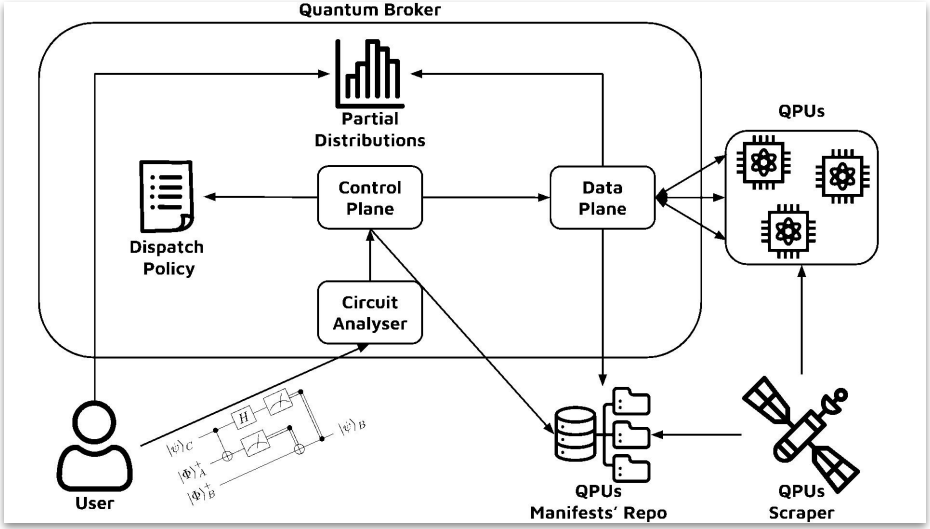
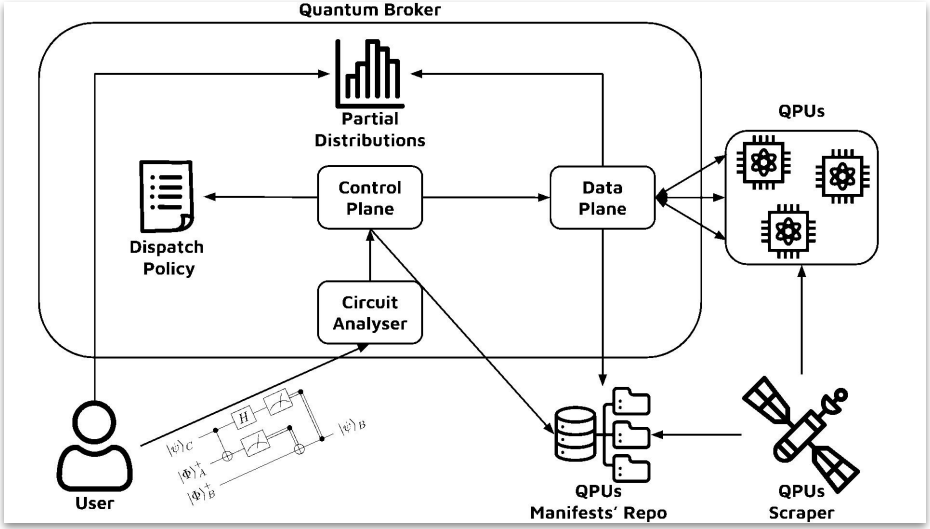


What happens if the Quantum Computer becomes **unavailable** while **executing my shots**?



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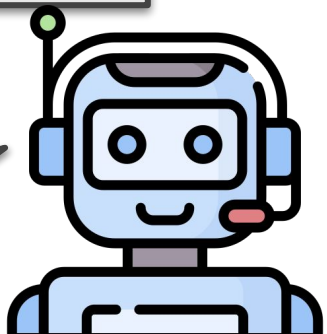
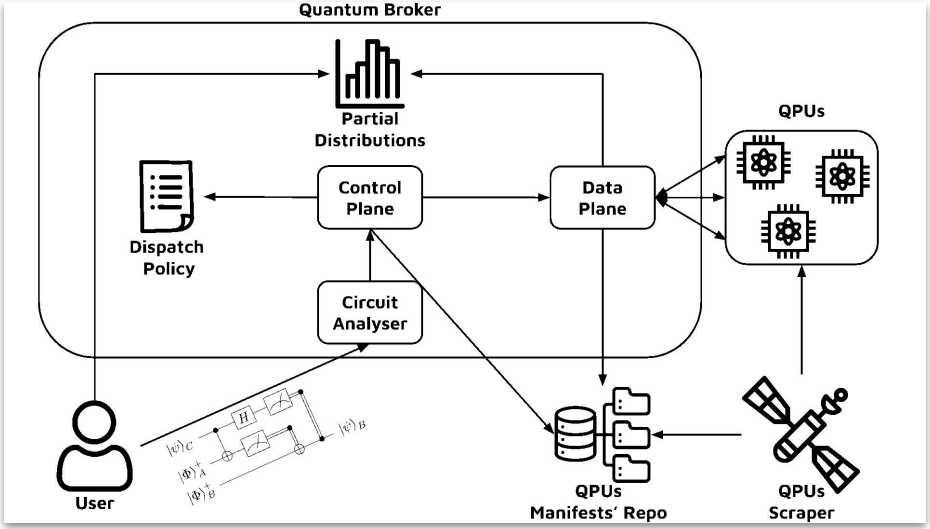
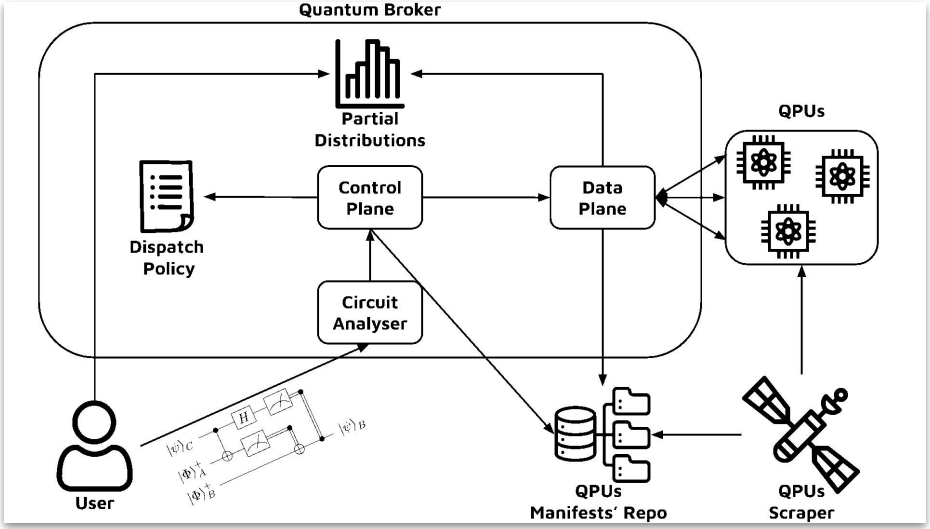


Other Quantum Computers are performing **other shots** and you can **access** the **partial distributions**!

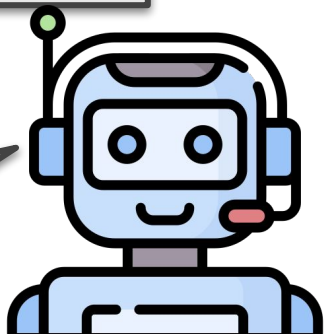


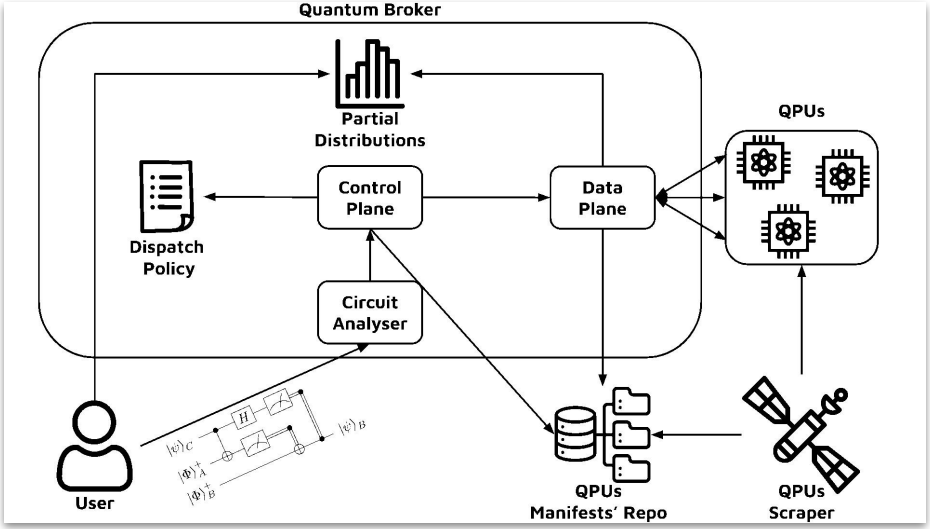
How can I **mediate** between my **cost**, **time** and **accuracy requirements**?



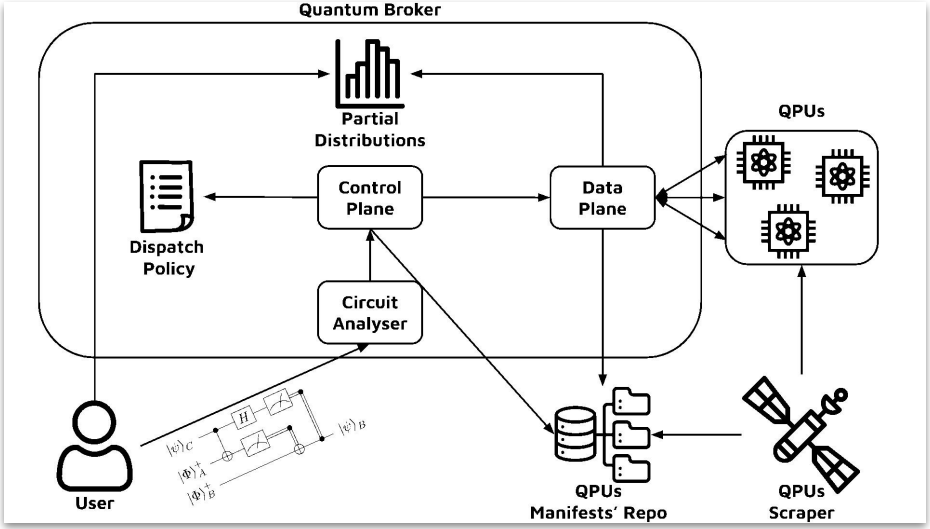
How can I **mediate** between my **cost**, **time** and **accuracy requirements**?

Exploiting **different** Quantum Computers to **distribute** my **shots** enables a **fine-grained management** of my **requirements**!



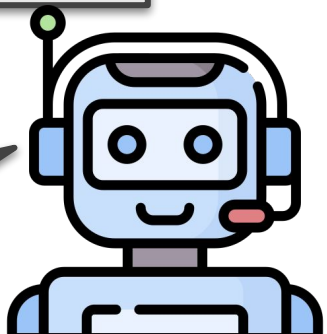


How can I **customise** the Quantum Computer's **decision process**?

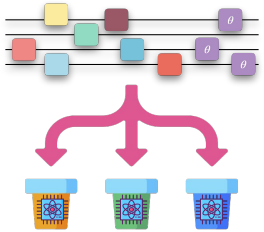


How can I **customise** the Quantum Computer's **decision process**?

The **dispatch policy** is **decoupled** from the **control plane**, so it is possible to encode **custom decision processes**!

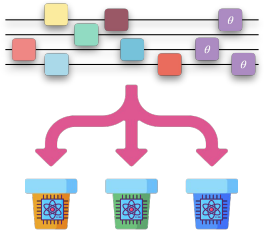


CONCLUSIONS



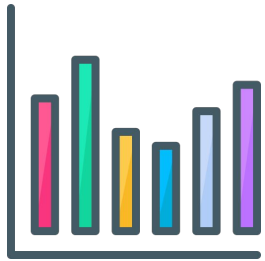
First proposal enabling the **dispatching** of **shots** among **multiple Quantum Computers**

CONCLUSIONS

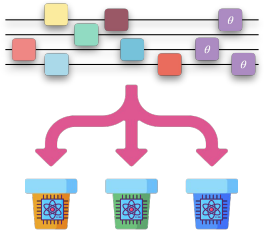


First proposal enabling the **dispatching** of **shots** among **multiple Quantum Computers**

Users can access the **partial distributions** associated to a **circuit execution**

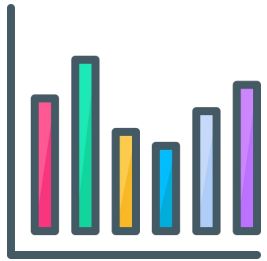


CONCLUSIONS



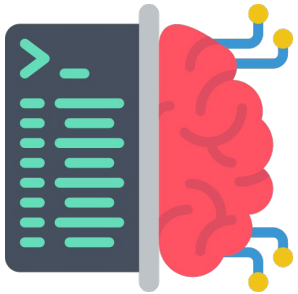
First proposal enabling the **dispatching** of **shots** among **multiple Quantum Computers**

Users can access the **partial distributions** associated to a **circuit execution**



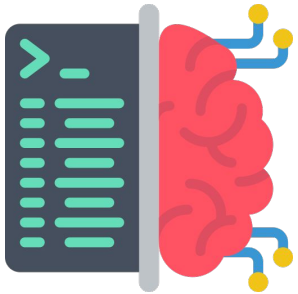
The **dispatchment decision process** is **decoupled** from the **control panel**: users can **customise** their own **policies**

FUTURE WORK

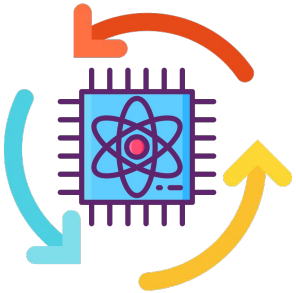


Machine Learning

FUTURE WORK

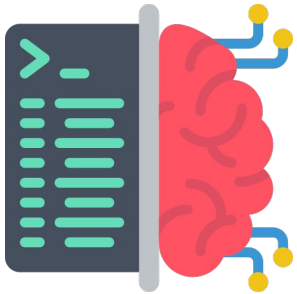


Machine Learning

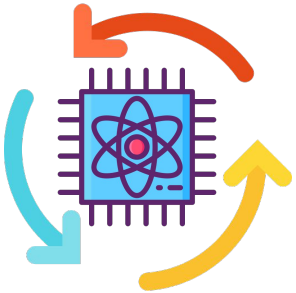


Variational Quantum Algorithms

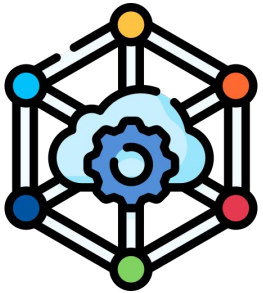
FUTURE WORK



Machine Learning



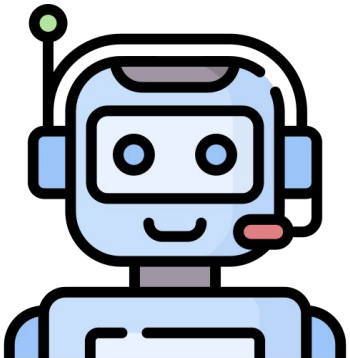
Variational Quantum Algorithms



Quantum Continuum

Thank you for your attention!

Any comment? Questions?



Dispatching Shots Among Multiple Quantum Computers: an Architectural Proposal

Giuseppe Bisicchia*, Jose García-Alonso, Juan M. Murillo and Antonio Brogi

*giuseppe.bisicchia@phd.unipi.it

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