accenture

QUANTUM COMPUTING WITH D-WAVE

An overview of the Accenture Quantum Program and use cases with D-Wave

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September 2019

Agenda for today and where we are now…

Accenture's Quantum Computing Program	*A brief overview of the Accenture Quantum program.*
Impact on Industries	*A focus on how the 4 of our 150+ use cases has a potential to impact selected set of industries.*
Kidney Exchange	*A specific story of a Kidney Exchange approach (patent pending).*
Q & A	*Q&A to learn more.*

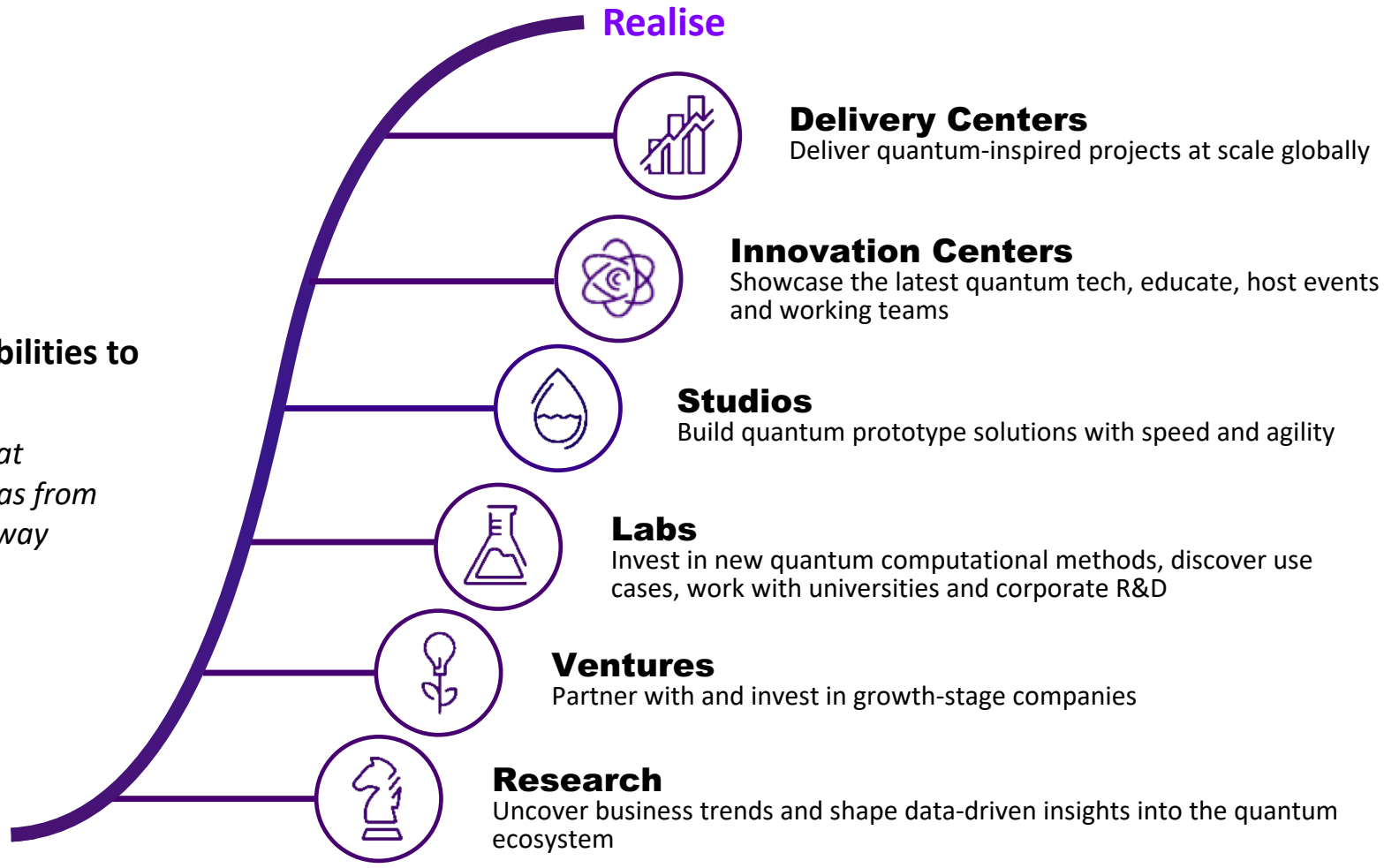
Setup for Quantum: Leverage the Innovation Architecture

Quantum computing is a journey and having the right information, partners, and talent is key to success. Accenture's Quantum Program is designed around our Innovation Architecture, a proven pipeline for scaling new technologies into market learning assets.

Qubit by qubit

Match Accenture's innovation capabilities to your own

Our teams foster a new way of working that convenes the best of Accenture to take ideas from initial discovery to co-creation and all the way through scale.

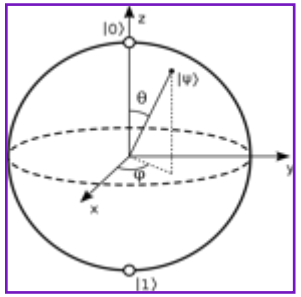


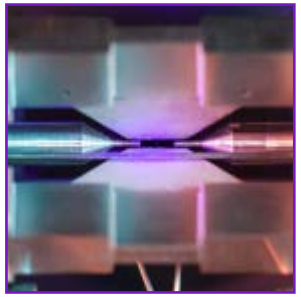
Work to be proud of: Paving new ground in quantum computing

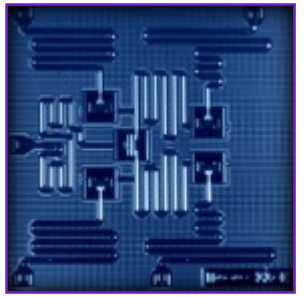
The Accenture Quantum Program was born from applied research. As quantum computers became accessible for use in the mid 2010's, we have been exploring their practicality against real world scenarios. This has enabled us to create a roadmap for new businesses.

INNOVATE

with us at the Quantum Zone, Labs and Liquid Studios







OFFERINGS

11 differentiated quantum offerings

PEOPLE

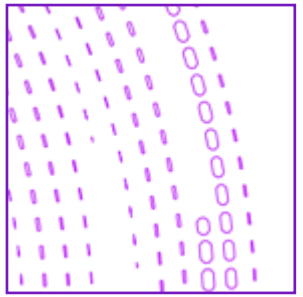
100 contributors around the globe

RESEARCH

150+ use cases, 3 integration patents

PROTO-TYPES

10 functional cross industry applications



Differentiation in the Market: Quantum at Scale

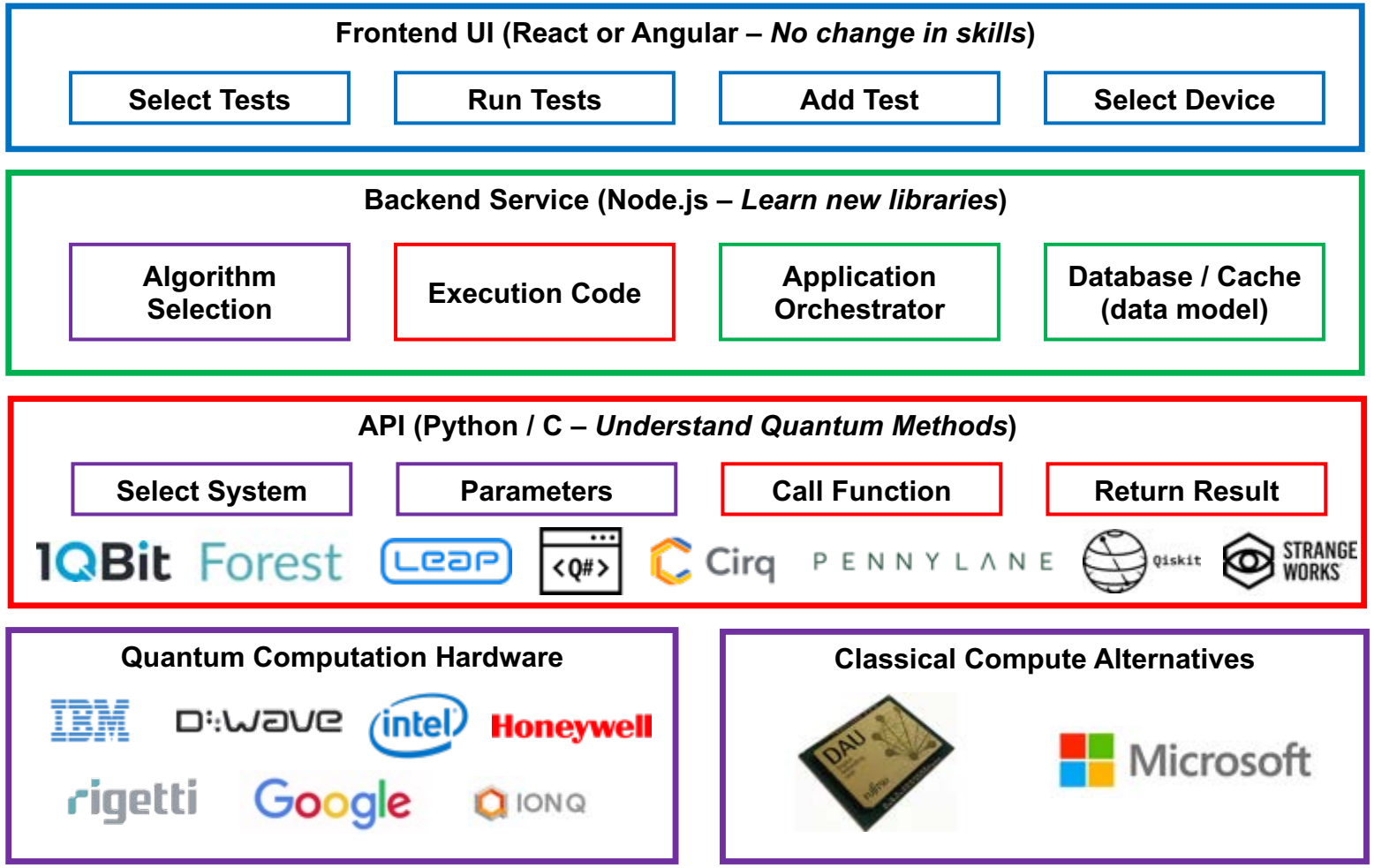
Creating useful quantum applications means leveraging the best technology across many parts of the ecosystem and having the right talent at all layers of the stack.

The Q Stack

Multidisciplinary approach to quantum development

Most enterprise's need to focus on the top and middle of the stack, which requires a business methodology rather than a scientific skill set. Preparing for a future in quantum means hiring or partnering for key roles, but mostly educating and training the existing workforce.

- Industry Expertise
- Delivery Leadership
- Service Designers
- System Architects
- Quantum Integrators
- Quantum Info Scientists



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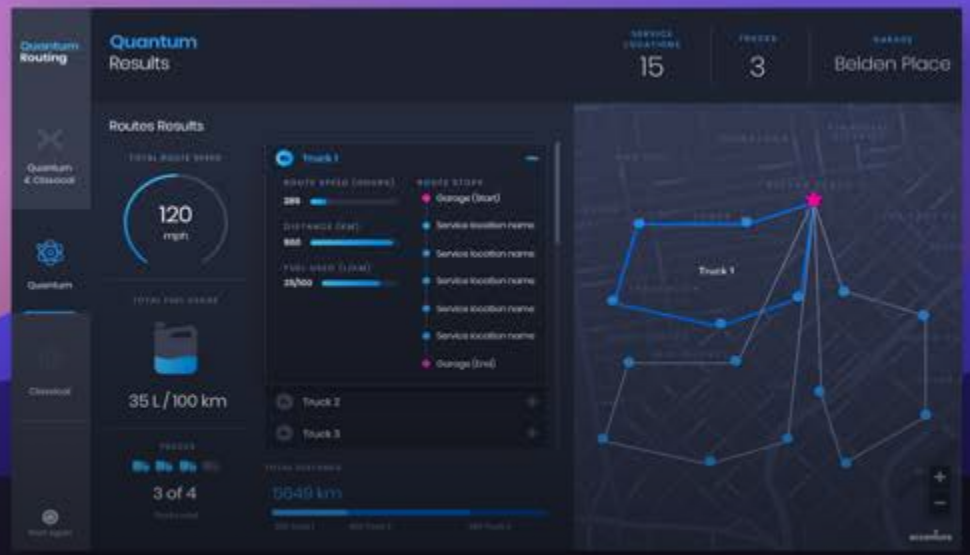
When the fundamentals change, everyone is affected

Let's focus on Finance, H&PS and others today from our 150+ use cases impacting these industries next

PRODUCTS	COMMUNICATIONS, MEDIA AND HIGH-TECH	HEALTH AND PUBLIC SERVICES	RESOURCES	FINANCIAL SERVICES
LIFE SCIENCES	COMMUNICATIONS & NETWORK PRACTICE	HEALTH Payers, Providers, Public Health	CHEMICALS & NATURAL RESOURCES	BANKING
RETAIL & CONSUMER GOODS & SERVICES	MEDIA, ADVERTISING & CONTENT	PUBLIC SERVICES Safety, Defense, Boarder Services	ENERGY	CAPITAL MARKETS
AUTOMOTIVE, INDUSTRIAL & TRAVEL	SOFTWARE & PLATTFORMS	PUBLIC SERVICES Global Cities, Post & Parcel	UTILITIES	INSURANCE
	HIGH TECH	PUBLIC SERVICES Pensions, Revenue		

QUANTUM

QUANTUM TRUCK ROUTING



Optimization engine that implements Quantum algorithms that solve for the real-time routing of vehicles to geographically diverse service locations. The solution would calculate the shortest route to each of the known service locations given a known set of constraints such as appointment time windows, location and capacity of vehicles and/or time/distance to each location.

TOOLS

- Simulator and QPU
- Angular
- Node.js
- Scikits learn
- Google & Bing Maps API
- C#

INDUSTRIES

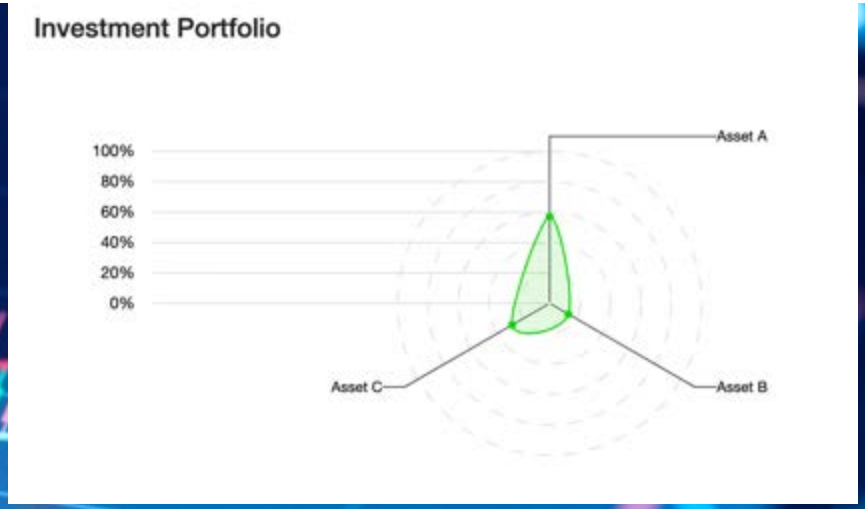
- Products
- Communications & High-tech
- Health & Public Services
- Resources

RESULTS

- Demonstrate Quantum Computing basics with interactive demo
- Successfully calculate optimized routes using quantum computing
- Show Classical vs. Quantum results comparison
- Explain use case with engaging site

QUANTUM

PORTFOLIO OPTIMIZATION



Risk based asset allocation for financial portfolios using historical data. Leverages quantum methods including Variational Quantum Eigensolver and Quantum Approximate Optimization Algorithm, both of which have the potential to efficiently solve optimization problems.

TOOLS

- Simulator and QPU
- Python
- Angular

INDUSTRIES

- Financial Services

RESULTS

PROBLEM SPECIFICATION

Portfolio assignment on a set of financial assets to maximize the expected return aligning to a choice of risk-aversion

EXPERIMENT DATA SET

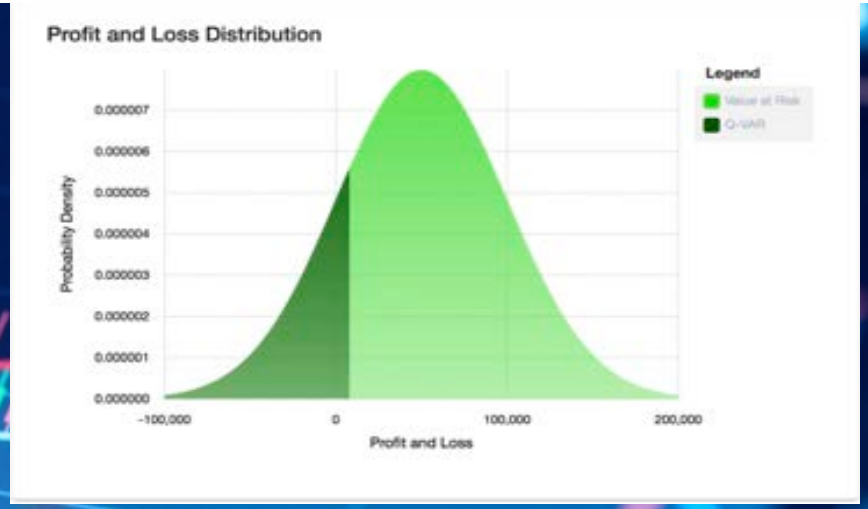
Statistics of a set of financial assets, which are either randomly generated datasets or a collection of historical data*

CUSTOM ENABLEMENT

Model the problem as a combinatorial optimization problem and perform customized problem reduction

QUANTUM

RISK ANALYSIS



The amplitude estimation algorithm integrated with a web interface in this demo is intended to show the path from determining basic statistical figures like expected gains towards more complex performance indices like both value at risk and conditional value at risk.

TOOLS

- Simulator and QPU
- Python
- Angular

INDUSTRIES

- Financial Services

RESULTS

PROBLEM SPECIFICATION

Quantifying portfolio investment risks to guide investment decisions depending on your risk threshold

EXPERIMENT DATA SET

Statistics of a set of financial assets, which are either randomly generated datasets or a collection of historical data*

CUSTOM ENABLEMENT

Identify challenges along the quantum software stack from gate-level quantum back-end to web-application front-end

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TECH4GOOD AT ACCENTURE

*"**Technology for good** is the **innovative application of emerging technologies** to ensure sustainable development, which not only creates a positive and **lasting impact across various social and environmental issues** but also offers **huge opportunities for growth to businesses**."*

QUANTUM

KIDNEY EXCHANGE

This demo shows how a kidney exchange is reformulated as a cycle-matching problem, which is known to be NP-Complete and intractable on classical computers. We further demonstrate a mapping of this problem to a quadratic unconstrained binary optimization (QUBO) problem, which may be solved by the D-Wave annealer.

TOOLS

- Simulator and QPU
- Ocean
- Docker
- Django
- D3JS
- React

INDUSTRIES

- Health & Public Services

RESULTS

PROBLEM SPECIFICATION

Finding optimal matches in a kidney exchange network through solving a cycle-matching problem.

EXPERIMENT DATA SET

Randomly generated datasets based on a statistical model of patient-donor attributes.

CUSTOM ENABLEMENT

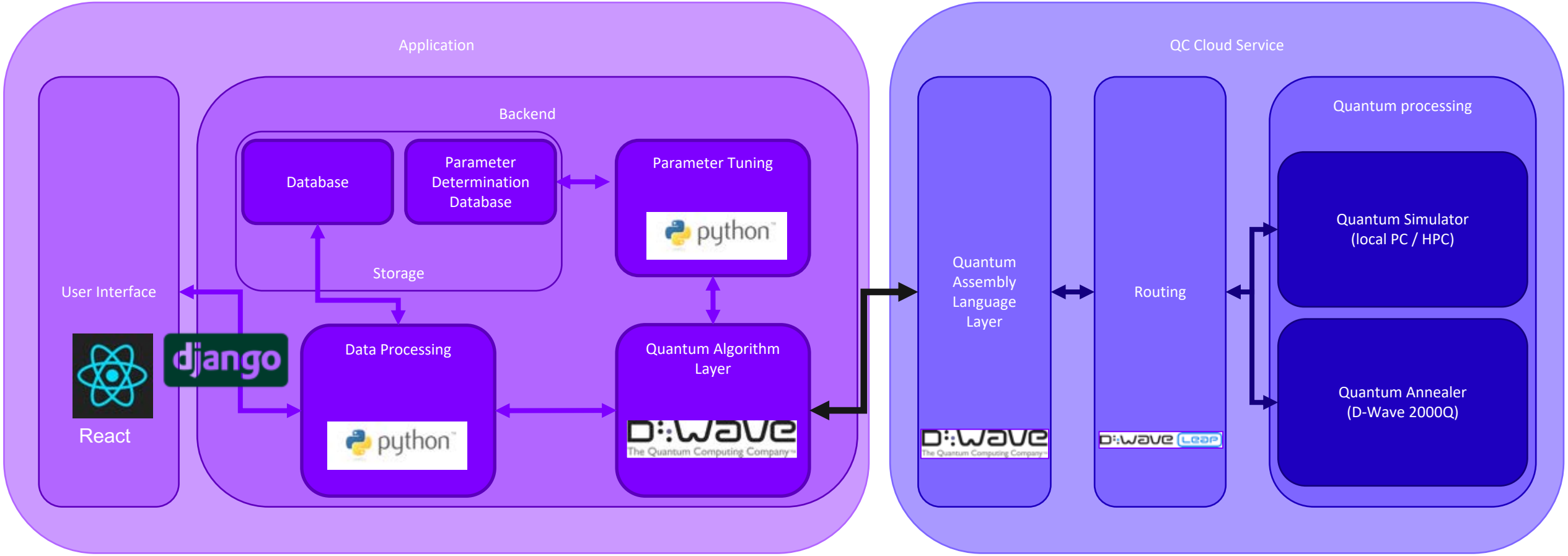
Implemented and optimized a unique mapping to a quadratic problem.

QUANTUM KIDNEY EXCHANGE

OUR TEAM UNDERWENT CHALLENGES FROM IDENTIFYING THE PROBLEM TO SOLVING IT…

	Problem description	Identify relevant quantum algorithms	Mathematical formulation	Problem mapping and reduction	Quantum software-dependent programming	Product delivery, analysis, and improvement
The challenge	• **Identify a suitable experiment with quantum methodology** - The vast number of ways to formulate a problem. - The limited set of quantum algorithms currently available. - Tradeoff between complexity and feasibility! - Use the existing criteria and develop an algorithms.		• **The original exchange problem can be mathematically formulated in various ways.**	• **Many ways to perform problem reduction, which are relevant to the solution performance.**	• **In programming, input format for quantum algorithms depends on the software platform and the functions used.**	• **Innovate further.** • **Scaling.** • **Process.** • **Selling.**
The outcome	• **Receive data representing an exchange problem.** • **Determine integer programming formulation of the exchange problem.** • **Map integer programming formulation to a QUBO formulation.** • **Obtain solution to exchange problem from QC resource.** • **Apply exchange decision based on the solution to an exchange problem.**	• **Consider quantum algorithms that perform optimization tasks.** - Quantum annealing on annealers, which requires a mapping reduction to a QUBO problem. - Quantum approximate optimization algorithms on gate-model device, which requires a mapping reduction to an Ising problem, or specific quadratic problems.	• **Initial problem formulation:** $\max_{C^* \subset C} f(C^*)$ w.r.t. $c \cap d = \emptyset,\ \forall c, d \in C^*$ • **Integer programming problem formulation:** $\max_{x_{i,j} \in \{0,1\}} \sum_{\substack{i,j \\ e_{i,j} \in E}} w_{i,j} \cdot x_{i,j},$ w.r.t. a set of our customized constraints.	**Map to a quadratic unconstrained problem.** - Mapping the integer programming formulation of the exchange problem to a quadratic unconstrained binary optimization (QUBO) problem, where W F(X,y) is the penalty cost function, and W is the penalty value: $\sum_{e_{i,j} \in E} -w_{i,j} \cdot x_{i,j} + W \cdot F(\mathbf{X}, \mathbf{y}),$ - This can be easily mapped to an Ising problem for other QC methods.	• **Generate self-defined functions for D-Wave customized to our problem formulation.** - Functions that generate the input for QUBO. - Functions for performing post-processing.	• **Build a UI that is easy to comprehend, and showcase a demo utilizing the QUBO algorithm.** • **Analyze the performance, and consider improvement.**

KIDNEY EXCHANGE HIGH-LEVEL ARCHITECTURE



WHAT'S NEXT?

THERE ARE CHALLENGES, WHICH CAN BE ENABLED IN THE NEXT ITERATION OF THE HARDWARE AND INTEGRATION TO OTHER SYSTEMS.

INNOVATE FURTHER…

SCALE MORE

- Continue research in to the area further; improve the algorithm.
- Our solution was limited to small network sizes.
- Expanding to general hospital management, and beyond.

IMPROVE PROCESS

- Work with governments and organizations to improve processes to map.
- Optimize for more realistic scenarios.

CUSTOM ENABLEMENT

- Implemented and optimized a unique mapping to a quadratic problem.

EXPERIMENT DATA SET

- Build and connect to the broader datasets available via UNOS (pair group of patient-donor of 75K lists).
- Test over multiple different hardware.

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