WHITE PAPER

THE FUTURE OF FINTECH

Applied Quantum Optimization In Payment Fraud Detection

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Overview: Fraud detection optimization using quantum computation

Payment fraud is a major challenge throughout the economy, and fraud mitigation is among the most challenging issues facing financial institutions. A recent PwC study found that fraud costs businesses an estimated $US42 billion in direct losses in 2020.[1] Beyond direct financial losses, payment fraud causes reputational damage to merchants and financial institutions, drives the cost of payment acceptance higher and produces poor CX that can translate into customer attrition.

Despite increasing sophistication in fraud prevention algorithms, attackers are innovating new ways to commit fraud, resulting in a technology arms race. Fraud defenses require optimized solutions to prevent attacks – before it's too late.

USE CASE ABSTRACT

This use case explores basic quantum computing concepts applied to complex practical contemporary challenges, like payment fraud detection. Effective fraud detection requires the ability to process massive amounts of data in near real-time. Quantum optimizing techniques take remarkably less time to process data relative to classical computing. This paper examines basic quantum computing concepts and explores how quantum annealing can accelerate data analysis and detection capabilities to better combat payment fraud.

Quantum computers may offer a definitive edge in the battle against payment fraud. Quantum computers gain an edge over classical computers by enhancing and exponentially increasing the speed of complex calculations. In 2019, Google's 54-qubit quantum processor, Sycamore, was able to perform a calculation in 200 seconds that would have taken 10,000 years for even the fastest classical supercomputers.[2]

Legacy pattern detection algorithms are especially vulnerable to performance degradation during peak usage periods. These performance gaps in fraud detection are costly to financial institutions, merchants and consumers. This power of exponential speed, derived from the concepts of quantum superposition and quantum entanglement, helps us re-evaluate numerous possible solutions to optimizing fraud-detection algorithms.

Optimization of these algorithms requires faster processing speeds to process more iterations in near real-time to properly identify transactions as either valid or fraudulent. **Quantum computing thus represents a paradigm shift that offers practical insights and solutions into optimizing effective real-time fraud detection.**

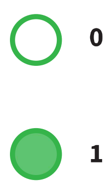
[1] "PwC's Global Economic Crime and Fraud Survey 2020. Fighting fraud: A never-ending battle." PwC, 2021.
[2] John Martinis and Sergio Boixo, "Quantum Supremacy Using a Programmable Superconducting Processor." Google AI Blog, Wednesday, October 23, 2019.

QUANTUM COMPUTING CONCEPTS

Qubits

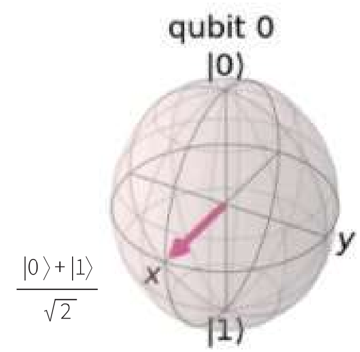
In a quantum computer, a quantum bit – or qubit – is the basic unit of quantum information. In classical computing, data is binary encoded into 0s and 1s, and all bits must be one or the other. In contrast, qubits are encoded into basic states of |0> and |1>.
The qubit has an advantage over classical bits with the principle of superposition, allowing the bits 0 and 1 to be in superimposed states where it can be 0 and 1 at the same time. **Superposition allows quantum computers to process multiple parallel threads of information at massive scale.**

Fig A: Classical bits are either 0 or 1



CLASSICAL/DIGITAL BIT

Fig B: Quantum superimposition of states can exist anywhere in the sphere



QUBIT

Quantum superposition

Quantum superimposition is a foundational quantum mechanics principle where a system can be in different states at the same time and that every state represents the sum of other states superimposed on one another. Rather than being binary, qubits can be 0 and 1 simultaneously.

In quantum computing, the Hadamard gate helps transform the quantum state into the superposition state. This principle can be represented as a qubit in Bloch sphere:

Fig C: Hadamard Circuit

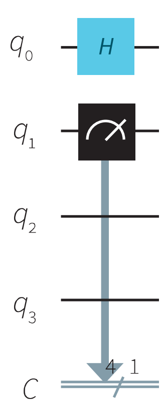


Fig D: Qubit at state |0> 1

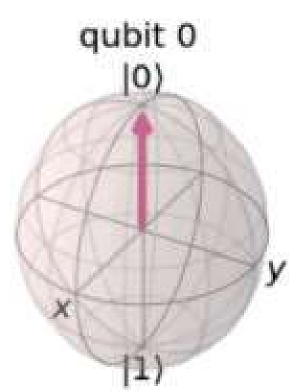
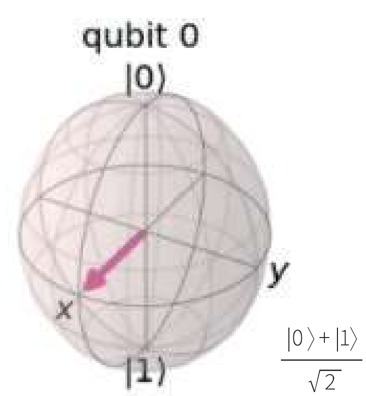


Fig E: Qubit at superposition state



Quantum entanglement

It's often said that everything is interrelated. **Quantum entanglement is the physical phenomenon of particles interacting such that the quantum state of each particle can't be described independently of the state of the others.** In quantum entanglement, individual elements lose their own individual destiny and are inextricably linked to each other, even when spatially distant. Quantum entanglement has profound implications for interdependent systems like fraud detection.

Fig F: The interdependence of quantum entanglement.

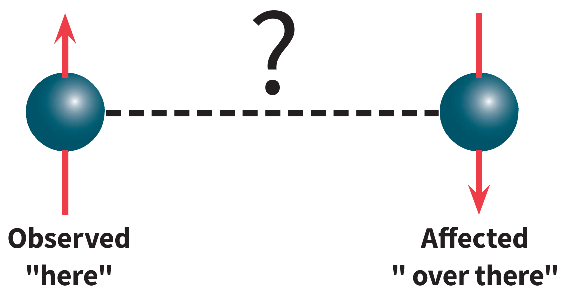


Fig from NASA.

FRAUD DETECTION IN THE PAYMENTS INDUSTRY

A combination of quantum computing and classical machine-learning algorithms can significantly boost processing speed and thus enhance the performance of real-time fraud-detection tools.

Let's compare today's classical approach with one that leverages quantum optimization.

False positives and the limitations of classical computing

Fraud detection efforts face challenges using classical computation methods, especially with false positives. Fraud is often discussed purely in terms of blocking illegitimate transactions, but there's more to the equation. False positives occur when algorithms incorrectly identify valid payment transactions from legitimate cardholders as fraudulent.

False positives can be a worse outcome than actual fraud. False positives cost merchants directly by obstructing sales, while issuers carry the dual burdens of fraud investigation and managing unhappy cardholders. False positives produce poor customer experiences that can have grave implications for long-term customer value. Merchants face a loss of customers, while financial institutions can lose top of wallet status, or worse, lose a cardholder account entirely.

False positives often arise from a limitation in the ability to map two sets of data. This limitation grows more significant and only increases once data starts mapping and creates a dense grid. Power consumption surges and computationally the possible outcomes are neither efficient nor fast.

Classical computing is incredibly powerful, but is limited in its ability to find patterns, perform classifications and make predictions in near real-time due to limitations in the ability to map diverse data sets. **Optimizing payment transactions at a global scale to prevent fraud and minimize false positives will require more predictive analytic power than classical computational approaches afford.**

Proposed quantum optimization solution

Quantum computers can exploit the superposition principle, enabling the quantum computer to process 2^n value. Entanglement makes it possible to evaluate data simultaneously and generated abundant possible outcomes, increasing efficiency and thus effectiveness. A number of algorithms and methods can be used to test for optimization:

1. Grover's algorithm
2. Monte Carlo simulation
3. K-Nearest Neighbors
4. Random Forest
5. Support Vector Machines (SVM)
6. Regression method

Optimizing algorithms using quantum

Quantum computing is an ideal method for finding better solutions for optimization problems. Quantum principles allow the sorting and processing of a large volume of data to arrive at the ideal decision.

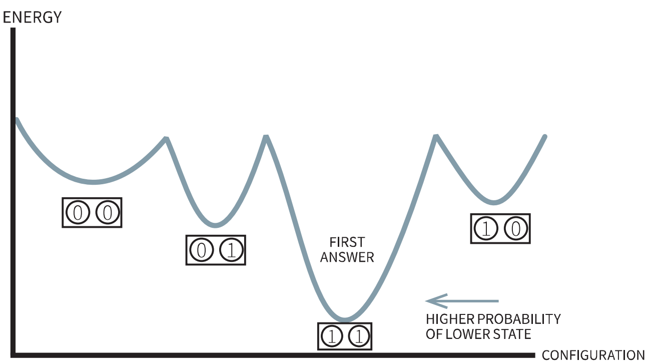
An example is using quantum principles to solve The Bernstein-Vazirani Problem. A quantum computer can find the hidden string of bits in the black box function in one shot with 100% confidence. In contrast, a classical computer would have tried several times depending on the length of the bit string.

Classical computers process information sequentially. A quantum computer processes it in parallel, with superimposition and entanglement creating the ability to output numerous possible outcomes. Quantum computers help solve challenges posed by the inherent processing limitations of classical computers and algorithms. There are different ways to implement quantum optimization algorithms in quantum computers, such as quantum annealing.

Quantum computing remains in its infancy with many concurrent approaches being pursued to develop and build a quantum computer. One of the approaches is quantum annealing. **Quantum annealing uses the intrinsic effects of quantum physics to help solve certain types of problems, called optimization problems.**

A related problem to quantum annealing is called probabilistic sampling. An optimization problem tries to determine the best configuration out of many different possible combinations to speed up processing and save time. If you're trying to build a Formula 1® sports car, for example, you're working with limitations on the configuration and a set of rules that seeks to provide a level playing field. You want a car that is lightweight, powerful and aerodynamic. The aim is to choose the parts that fit best for car in all three aspects. An optimization problem tries to find the best configuration to speed up the performance.

Fig G: Energy, global minimal state



Physics can be used to solve optimization problems because it can frame them as an energy minimization problem.
A fundamental part of physics is that everything's always trying to find its minimum energy state, so objects slide down hills, or in thermodynamics hot things cool down over time.

Similarly, **quantum annealing uses quantum physics to find the minimum energy state of something.** Sampling problems are related to optimization problems, but they are slightly different. Instead of trying to find the minimum energy state, we're trying to sample from many low energy states and then characterize their shape. This is useful for applications such as machine learning, where you're trying to build a probabilistic representation of the world and these samples give you information about your model.

We can use these principles to improve our models over time. Optimization problems also crop up in machine learning. Typically, sampling problems and optimization problems are very difficult to solve on classical computers. There is a lot of interest in trying to find alternative techniques to solve this type of problem.

So how does quantum annealing relate to the other forms of quantum computing?

In quantum annealing, it is technically more difficult to get qubits to work together coherently in a quantum computer. However, there are powerful algorithms developed for use when they reach scale. Examples include Shor's algorithm for factoring large numbers and also Grover's algorithm for searching through databases. Each promise results significantly faster than anything you could run on a classical machine given current knowledge.

Simulating quantum circuits, gates and programming

There are a variety of online tools that can be used for simulating quantum circuits, gates and programming:

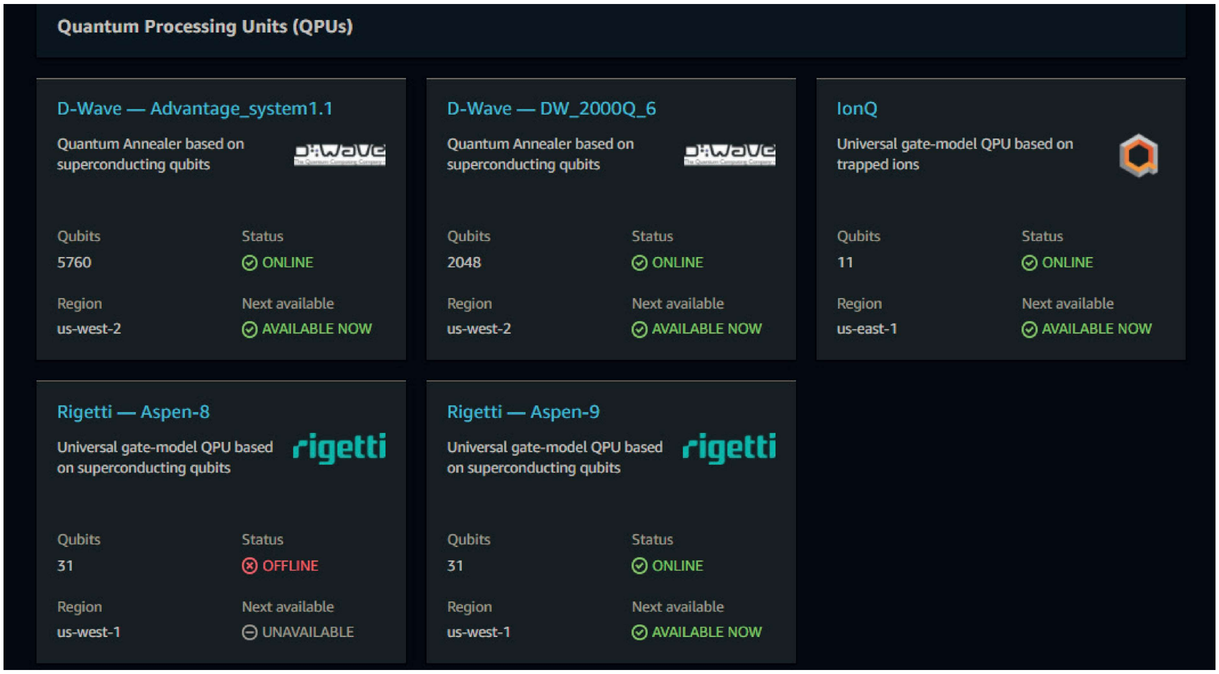
1. Amazon Braket
2. IBM Qiskit
3. TensorFlow Quantum
4. Microsoft Azure Quantum

We have used Amazon Braket for our use case.

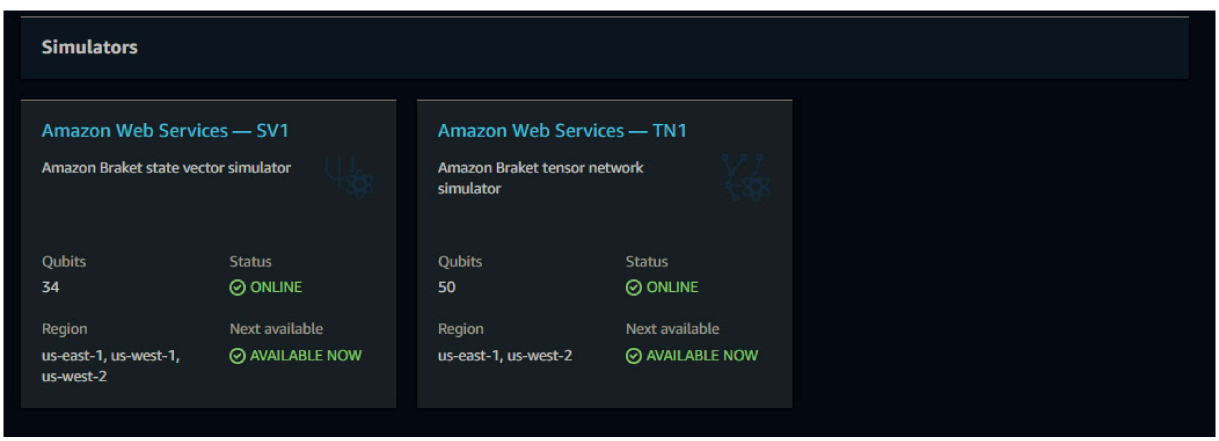
Amazon Braket

AWS's Braket is a network that currently has three quantum computers and two simulators. Scripts can be created in Python. Within Braket exists "Notebooks" where code is written and executed. Amazon Braket differentiates from competitors like Google and IBM because Braket uses multiple quantum devices. Braket uses two D-Wave, two Rigetti and one IonQ quantum computer chip sets. Braket also provides their own quantum simulators that are actually classical computers that simulate quantum computing.

Amazon Braket devices

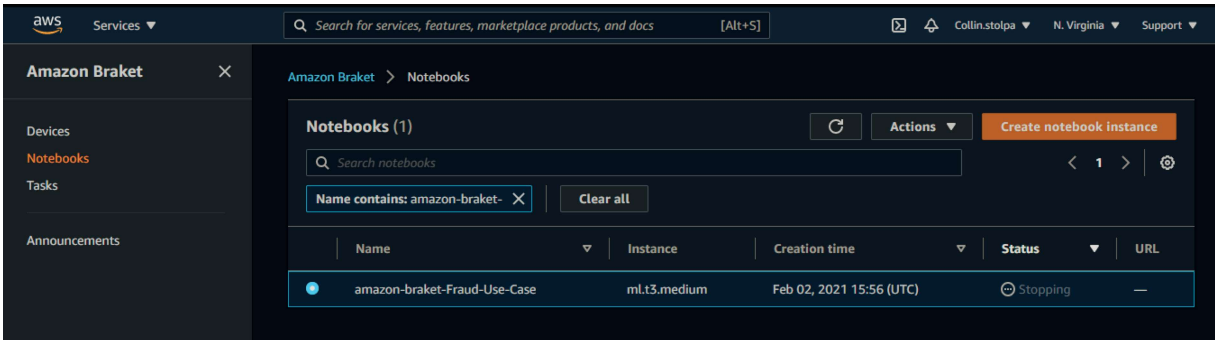


From this page we can select quantum computers and understand how the qubits are entangled with each other. Each QPU will show the number of qubits available, its status and availability. Above is a list of all the quantum computing circuits available, below is the list of the Braket simulators.



These simulators mimic the way a quantum computer works. Given the early stages of quantum computing, these simulators are beneficial as they allow for more accurate computation and will have more up-time compared to the actual quantum chip sets.

Amazon Braket Notebooks



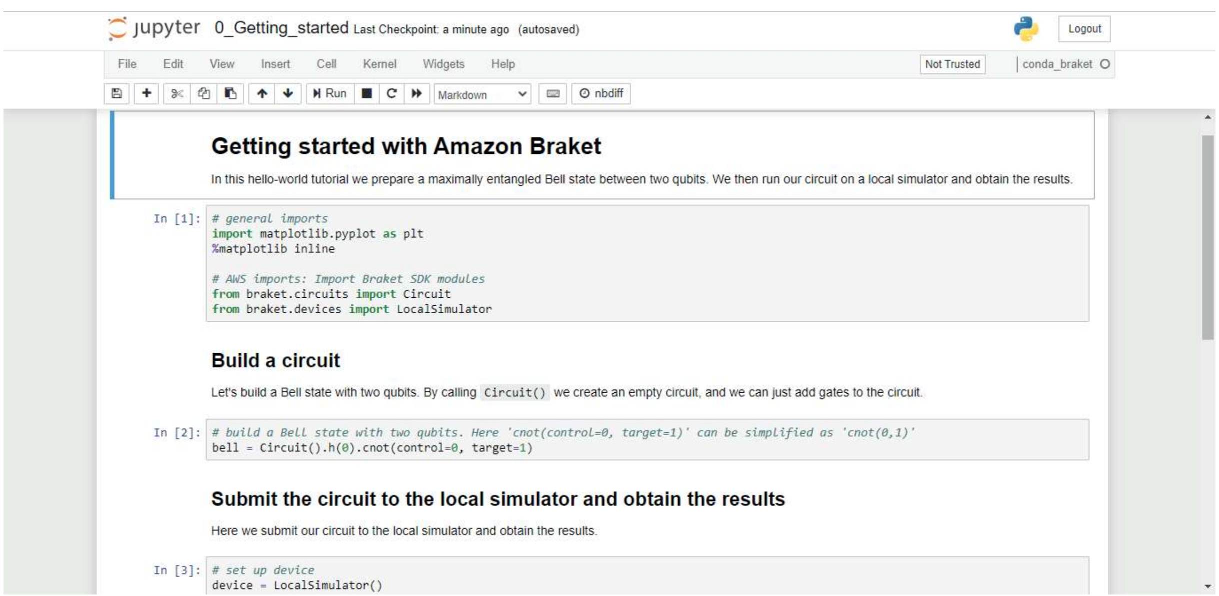
This is a list of instances that spin up cloud resources that come pre-installed with the Braket SDK, so nothing needs to be installed to run on the devices.

Tasks

Tasks are run and results shown on the available quantum devices.

Creating a task

These tasks are created within a Notebook. The language used to create a task is done in Python. Here is an example of their "Hello World" example:



Fraud detection use case

Effective fraud detection is vital to the fintech industry. Fraud detection can be cumbersome on even the fastest classical computers due to the amount of data points that need to be examined for every transaction. Quantum computers can run algorithms multiple times faster than classical computers. A quantum computer's speed can detect fraud faster and with greater accuracy. **Those exploring quantum computing options with Amazon Braket today will be best positioned to scale next-generation fraud defenses and optimization when quantum computing becomes more readily available.**

Insights into the quantum computing ecosystem

There are a number of global initiatives around quantum computing which are growing at rapid speed within startup ecosystems, research groups and various industries. Quantum computing is understandably attracting significant investment. Some of the organizations that are aggressively investing in quantum technology include Alibaba, Amazon, Google, IBM, Intel, Lockheed Martin and Microsoft.

Scientific progress in this area is advancing rapidly through continuous global development. Consensus estimates for the global enterprise quantum computing market project 30%+ CAGR in the next several years (Allied Market Research projects 31.7% CAGR through 2025 to reach to $5.9B).[3]

Conclusion

Quantum computing holds promise to be a significant disruptive force in fintech. Enhanced quantum algorithms offer significant speed enhancements that can help us optimize existing problems. Quantum computing is still an immature technology, but one in which significant investment is being directed by leading brands in finance and technology. Now is the right time for fintech organizations to establish working competency with quantum computing concepts in order to realize (and monetize) the benefits of the technology as it matures. Such initiatives would help mitigate against organizations exercising monopolistic control and disproportionate market share in the future. Early adopters to this technology stand to develop expertise that will allow them to aggressively compete and establish an edge over marketplace competitors.

[3] https://www.alliedmarketresearch.com/enterprise-quantum-computing-market

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