Quantum Computing in High Frequency Trading and Fraud Detection

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ABSTRACT

'Quantum Computing in high-frequency trading and fraud detection' is an analysis of quantum computing and how it can be used by the different industries especially finance. It is an evolution of computing from the traditional computing method. Quantum computing is a process that is concentrated on creating systems and technology based on quantum theory rules. Quantum theory describes the energy on atomic and subatomic levels. Quantum computing uses quantum bits (qubits) which are more advanced than the traditional bits used by traditional computers. This article focuses on deploying quantum computers in solving problems that cannot be efficiently solved using traditional computers. In the finance sector, such as banking, insurance, and high-frequency trading, quantum computers can help optimize service by providing targeting and predictive analytics to reduce risk, provide personalized customer service, and provide the needed security framework against fraud.

Key words:
Quantum Computing, Qubits, Fraud Detection, Atom, Entanglement

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INTRODUCTION

Quantum computing can be utilized in finance and high-end trading. Its ability to categorize and analyze data for predicting outcomes is unrivaled. Several technology companies have started to invest in a quantum computing system as it is seen as the future of computing.

Financial Service providers such as banks, insurance, and trading platforms may utilize quantum computing processes for trade optimization, risk profiling, and targeting and predictions. These would help enhance activities in finance and also improve customer service delivery (Donepudi et al., 2020a). Aside from the various benefits in the economic environments, quantum computers are used in several other industries such as Agriculture, manufacturing, health, education, and so on.

QUANTUM COMPUTING

This is an aspect of computer processing that concentrates on creating machines, computer systems, and technology using the tenets of quantum theory. Quantum theory describes the energy on the level of subatomic and atomic. Unfortunately, the information encoding is done only in bits of 1 or 0 in modern-day computer usage. This restricts its ability.

However, in quantum computing, encoding is done in qubits or quantum bits (Asadullah et al., 2019). Quantum computing adds to a unique subatomic feature that makes it possible for them to exist in multiple states, for example, a 0 and a 1.

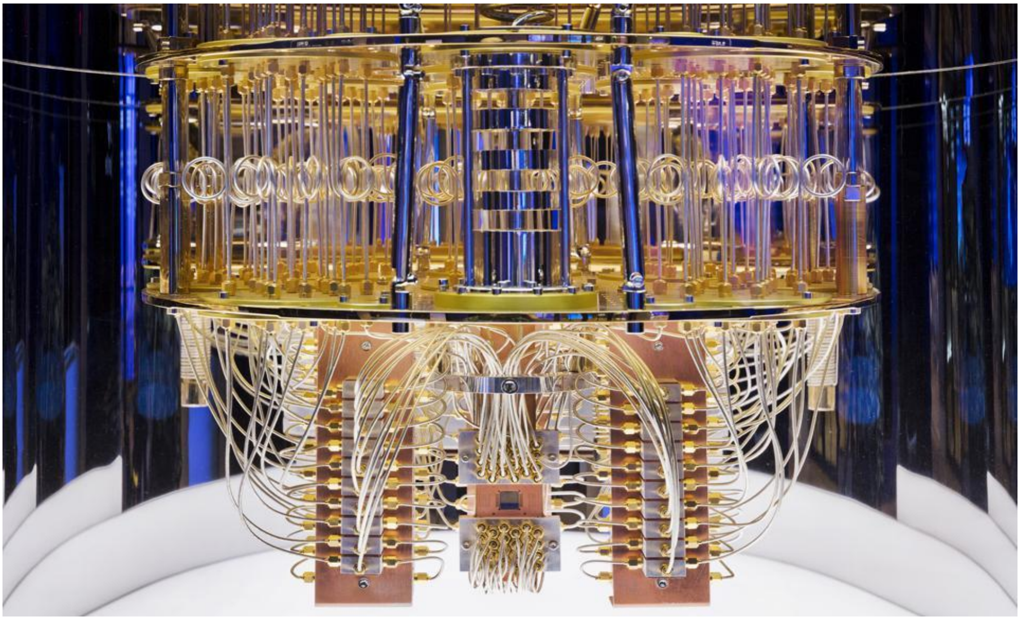

Figure 1: IBM quantum computer (Source: forbes.com)

Supercomputers are based on two quantum physics, entanglement, and superposition in understanding quantum computing. This feature enables a quantum computer to carry out tasks using lesser energy and much higher speed than traditional computers (Paruchuri, 2015). In history, the subject of quantum computing started during the 1980s. Experts learned that several computer process issues might be efficiently solved using quantum algorithms instead of traditional algorithms (Ganapathy et al., 2020). Quantum computing may be utilized in several fields of drug manufacturing, finance, and intelligent, information technology, artificial intelligence, and heavy data search, finance, designing aerospace, nuclear fusion, digital building, and so much. Leading technology companies and enterprises like Google, IBM, Google, HP, Microsoft, Nokia, Alibaba, Airbus, Toshiba, NEC, Mitsubishi, SK Telecom, Volkswagen, Biogen, D-waves, Lockheed Martin, Raytheon, and Rigetti have been attracted by quantum computing and the potential size of its market.

TRADITIONAL COMPUTER VS. QUANTUM COMPUTER

Quantum computers and traditional computers process data differently. Traditional computers utilize 1 or 0 transistors. As stated earlier, quantum computers quantum bits (qubits). Quantum nits are both 1 and 0 at once. The network on qubits increases quantum computing power extensively. The connection of more transistors may only add to the capacity linearly.

Traditional computers are better used for ordinary functions that computers should complete. However, more complex tasks like carrying out simulations and analyzing data are best done with quantum computers. For instance, quantum computers can be used to simulate drugs or chemical trials for best results. However, these types of computers are much more challenging to manufacture and highly expensive to obtain. In addition, they must be stored in an ultra-cold environment.

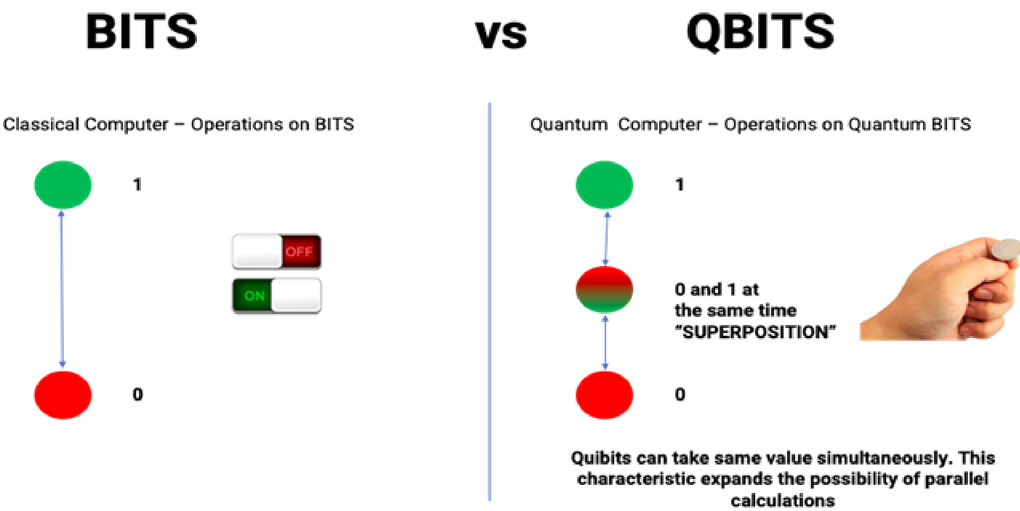

Figure 2: Bits vs, Qubits (Source: afzalibrahim.medium.com)

Traditional computing upswings include memory addition to boost computers. This is however minor task, a principal and more complicated task that quantum computers can undertake (Paruchuri, 2017). As a result, everyday computer applications such as Microsoft word or Excel may not run faster with the application of quantum computing. Quantum computing can, however, solve more complicated tasks faster.

For instance, the quantum computing system currently being developed by Google maybe be able to solve many machine process issues like boosting machine-learning training. It can also help in the manufacturing of batteries that are more energy efficient. Security features of quantum computing, among other uses, can help in the secure sharing of data and information. Quantum computing systems have been deployed in the medical field to help improve treatments. For example, it can be used to fight cancer by gathering data and carrying out efficient analysis that can lead to the production of new drugs or enhancement of previous cancer drugs. In addition, missile detection and radar can be improved with the help of quantum computing. Also, environmental factors can be enhanced by using quantum computing processes to detect water contamination with sensors.

QUANTUM COMPUTING PROCESSES

Using a traditional computer would be the best to explain quantum computers. The development of traditional computers brought the best bit of technological creation in the history of the world. However, traditional computing function is quite limited as there are several task and problem which the traditional computing systems might never help solve.

This is not wholly dependent on the problem of power, and it is the entire processing technique and method of calculation employed by traditional computers. However, there is a problem that traditional computers will never be able to solve, even if it remains for thousands of years. Moore's Law on transistors, even if it remains for hundreds of years, will not be possible to design complicated chemical Interfaces, enhance delivery routes, and several other issues.

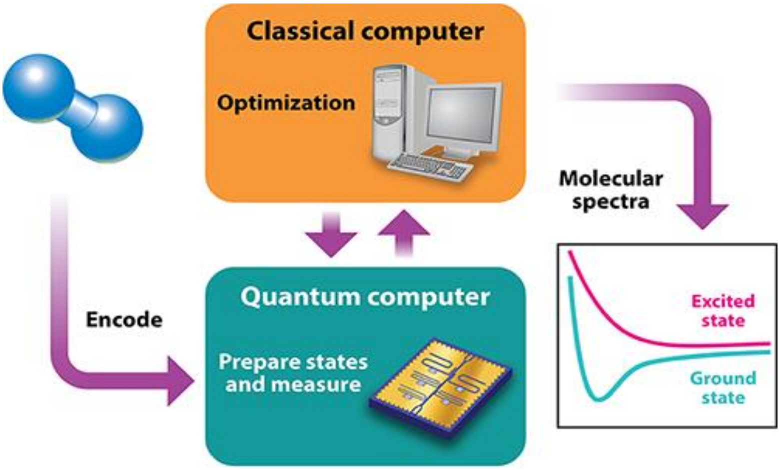

Figure 3: Quantum computing process (Source: physics.aps.org)

Most of the problems share similar features:

Connectivity outbursts when many and several connected variables each have to be analyzed side-by-side for an optimal result for the solution. Although, as the number of variables grows, the memory and time needed to process also increases immensely, this immense increase may likely be able to overpower the traditional computers, which must be able to predict and detect all the possible connections in time (it can take an unrealistic number of years), or it might lead to inaccurate and costly estimations. On the other hand, quantum computers can access a completely different computer processing system that can help solve those problems in more manageable and simpler steps. It does not need to test all the solutions in a sequence. The computer processing system is called quantum mechanics, which is complicated mathematics that explains the behaviors and interactions of atoms and other smaller atoms.

In traditional computing, bits are used and commonly characterized by tiny fractions of current from electricity and connected through unique gates (commonly made using transistors) to carry out computations. In quantum computers, there are models to replace the two concepts (Paruchuri, 2019). Quantum bit (shortened as qubits) instead of Traditional bits and quantum logic gates provide a way to utilize the highest abilities and features (i.e., entanglement and superposition) of the quantum system instead of traditional logic gates.

Qubits: in traditional computing systems, bit were limited to 1 or 0. It means a bit might either be 1 or 0, and no other possible was available. Using superposition, a qubit can be 1, 0, or a combination (complex) of both 1 and 0. This is sometimes referred to as "0 and 1 at the same time." This is both correct and wrong. Superposition lacks a straightforward analogue outside the quantum world. It would be pretty difficult to explain why except through quantum physics. Essentially, superposition enhances qubits and gives it more ability to compute and store data than the traditional bits.

Entangling many qubits gives them the ability to crack issues by functioning concurrently using a quantum logic gate. After the entanglement, the qubits can no longer be portrayed separately. Every qubit added to the entanglement creates the necessity to extensively increase the volume of data to describe the system's nature completely. This is different from saying entangling qubits gives you the freedom to process or store an exponential volume of data that is useful for computer processing. It is undoubtedly more complex than that, and this is because it will take us to a different area called quantum information theory, an emerging field.

Entanglement makes it possible to generate enormous computer processing power (that is a lot more than traditional computers) using a reasonably small amount of qubits. With as few as 50 best quality qubits, specific algorithms can be run in a matter of minutes. Such algorithms may take years to run using the best traditional computing system (Ahmed et al., 2020). There are lots of methods that can be used to make, entangle and control qubits. Superconducting is the most common and popular method of all. Superconducting utilizes solid-state fabrication to create synthetic qubits, which are almost the same as traditional computer chips, iced at freezing temperatures and monitored through pulses from microwaves. Google and other technology companies like IBM have made great strides using this technique which has made headlines.

Other techniques like employing the use of qubits from actual atoms. This type of qubits is entangled using electromagnetic forces in 3D spaces, ionized and controlled using lasers. This type of method offers some advantages over the other more popular method used by technology companies. For instance, they have the slightest error possibilities and the most powerful quantum computing program available.

QUANTUM COMPUTING POWER ASSESSMENT

At this point, a clear picture computer and what it encompasses should have been made. Different methods can be used to create a quantum computing system, and these methods create quantum computers at different levels, with different abilities and powers. A popular way to measure the power of a quantum computing system is to use the number of qubits.

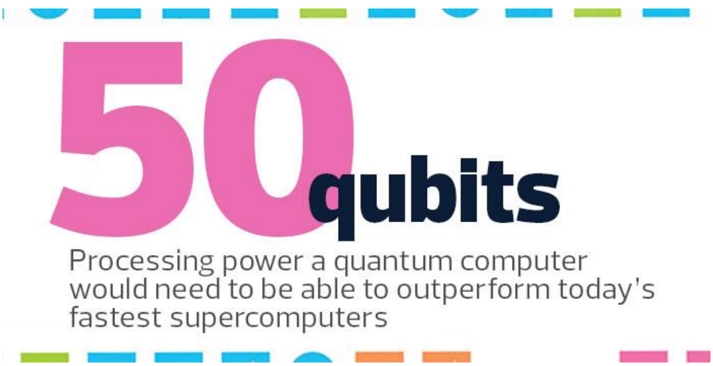

Figure 4: Quantum power (Source: fedtechmagazine.com)

This is because qubits remain central to quantum computing and seem like the best strategy. It is, however, not so helpful in providing the complete picture of the qubits' power to carry out essential computations. For instance, picture assessing railroad just on the sum of miles of track they have. Several other features like the volume of freight, railroad track runs, level of interconnection, and the number of tracks in good condition must also be involved. This is similar to quantum computers. To logically assess the power and ability of a quantum computer, it is essential to analyze its qubits and the entire system. Questions about connectivity, coherence, quality, and so on must be asked. There are five pieces of information you must find out:

Coherence time of qubits

The extent to which a qubit can retain its complex state of quantum, which is mainly a qubit's lifespan, is referred to as Coherence time. After a qubit is kept alone and put up in a quantum mechanical state, what is the length of time, it will last before decay? Theoretically, a qubit can maintain its state for infinity if it can be flawlessly singled out from its surrounding domain. However, practically, the minutest disturbance will disintegrate this highly fragile quantum state and destroy all the computation. Thus, it becomes a question of time, and duration is mainly connected to lately isolated the qubit is. Coherence time in systems like IonQ (a trapped ion system) is mainly calculated in seconds to minutes. Microsecs to milliseconds are used in solid-state systems. The importance of coherence time to quantum does not pertain to its use in understanding how adequately isolated the qubits are. It is also a way to find out the entire computation budget. All Quantum operations must be completed before the quantum bits lose data, information as well decohere. Thus, the more the coherence time, the bigger their power for complex, longer algorithms and an increase in the value of the computer.

Qubits connectivity

The ability of qubits to interact "talk" with themselves through an entangling gate is referred fo connectivity. Complete connectivity can be found in systems of trapped ions. Any pair of qubits can create gates in operation. However, in superconducting quantum computers and other technological processes, only physically adjacent qubits can function without employing intermediary quantum bit.

Identical qubits

Quantum bits must be as indistinguishable as they can be. When a quantum is scaled past a small number of quantum bits, creating a reliable connection between them will become a very difficult task if they are not connected. A difference in the frequency or any other thing, no matter how minor it may be, the turning and calibration of every qubit and how it connects with other quantum bits becomes a big issue. This is in the solid-state system. The minutest mistake in the production of a single synthetic atom can quickly become a nightmare. The use of real atoms by the trapped ion method makes the quantum bits inherently and identically perfect.

Gate fidelity

The number of gates that can be run is determined by Gate fidelity. It also defines the algorithm size that can be run. Just like traditional computers, the primary algorithm building blocks are logic gates. However, unlike traditional computers, quantum gates are not perfect, and the errors are added up quickly. These errors are usually reported quickly as gate error rates. However, it may also be shown in metric referred to as fidelity which is the error rate inverse.

The increase in error rate limits the profoundness of calculation, and it will lead to useless answers quickly. The advantages of having a large volume of qubit would be greatly affected by poor gate fidelity. Poor gate fidelity reduces the ability of a quantum computer. To make your quantum computer useful, gate fidelity must be improved whenever qubits are added. Logical qubits or error-corrected qubits are zero-error qubits generated through the combination of several physical qubits to one "logical" qubit. The amount is dependent on physical qubits fidelity.

This may be seen as the future of quantum computing, and it has not yet been created in hardware. However, many experts are working on making this possible.

Number of qubits

The qubits can now be counted. After you make certain that the qubits are identical and have an accurate coherence time and gate fidelity, the qubits can then be added to increase the quantum computer's power. The addition of qubits increases the computational power significantly. As the qubits are added, the size of the computational system multiplies. It becomes possible for Moore's law to be extended through the addition of one qubit in a year.

In summary of the above:

- An enormous amount of qubits with low fidelity and limited gate depth is relatively useless.
- Also, high fidelity with a small number of qubits isn't practical.
- A quantum computer with adequate fidelity to enable a minimum of n x n gates is perfect, where n refers to the number of qubits.

QUANTUM COMPUTING AND FINANCE

Application of the emerging quantum computing system and financial problems.

In the past several physics and mathematical science-related theories have been applied successfully by financial service providers in solving their most complex problems. For example, the black-Scholes-Merton prototype applies the Brownian motion concept in pricing financial devices. The application of quantum computing to financial problems, especially the constrained and uncertain optimization models, would bring a lot of advantages to the initial investors and users (Donepudi et al., 2020b). Think of the ability to calculate and discover flexible arbitrage chances that rivals and competitors cannot see. Aside from that, quantum computing may deliver specific benefits like enhancement of customer engagement using behavioral data, greater compliance, and quicker response to market volatility.

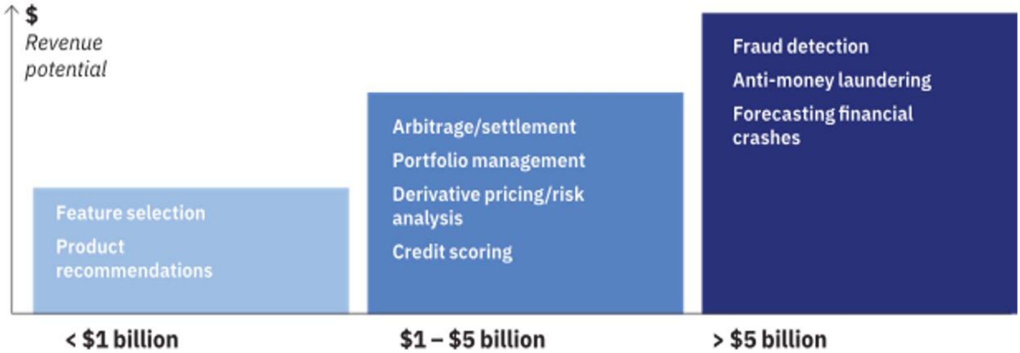

Figure 5: Quantum computing benefits in finance (Source: ibm.com)

How do these vast advantages result from quantum computing?

The quantum computers solution space is orders of magnitude more enormous than traditional computing systems (even more than supercomputers). This is because you need about twice the number of transistors working on the traditional computer is needed double its power (Azadet al., 2021). In a quantum computer, whenever a qubit is added, the power may closely be doubled. It may take several years for quantum computing to attain wide commercial applications. However, many experts predict it would lead to the breakthrough of several products and services that will solve particular business and financial issues effectively. Business organizations may also use quantum computing to restructure their operational processes like:

- Front and back-office opinions on customer oversight for "know your client," onboarding, and loan origination.
- Trading, Treasury, and asset management.
- Enhancement of business, including compliance and risk management.

We may classify the specific application of quantum computing into three primary categories:

- Targeting and Prediction
- Trading optimization
- Risk Profile

We shall explore the possible scenarios in financial services, like insurance, financial market, high-end trading, banking, where quantum computing can be applied.

Figure 6: Targeting & prediction, trading optimization and risk profiling (Source: ibm.com)

Targeting and Prediction

Modern-day customers in financial services prefer user-specific services and products that fit and predict their ever-changing desires, needs, and behaviors (Vadlamudi, 2019). Over twenty percent of small and medium-sized financial institutions have lost clients because they don't offer clients personalized products and services that prioritize clients' experiences.

Creating analytical systems that can go through stacks of data (behavioral) accurately and quickly enough to detect the products and services required by a particular client in real-time is quite tricky (Verma et al., 2021). This has negatively affected financial institutions that affect their ability to provide preemptive service and product suggestions with enhanced detail selection in an aggressive way. This also affects fraud detection. According to research, an estimated amount of USD 20 billion and 50 billion revenue is being lost by financial institutions yearly due to poor management of data and fraud. Systems used in fraud detection are usually inaccurate. It returns eighty percent false positives and makes the financial service providers be high risk-averse (Donepudi et al., 2020c).

To enable accurate load assessment, the process for onboarding clients may take up to three months. In modern age banking, which is mainly done digitally, clients will not want to wait for such a long period. More and more financial institutions lose new clients to their more active competitors because of their slow and ineffective onboarding processes.

Quantum computing would surely be a game-changer for customer prediction and modeling. It is expected that the ability of quantum computers to model data would undoubtedly be more advanced in discovering patterns and sequence, carrying out classification and categorization of data, and predicting outcomes that cannot be made currently due to the complex data structure issues.

Trading optimization

The complex nature of trading activities in the financial markets is on the increase. For instance, the derivative model for adjustments of valuation has skyrocketed. It currently includes debit (DVA) credit (CVA) margin (MVA), Capital (KVA), and funding (FVA). The strict regulatory requirements put in place by regulators for higher transparency made the validation processes in trading stricter. The impact on risk management computations must be synchronized with credit exposures of counterparty and loan limit uses of derivatives portfolios (Ahmed et al., 2021b). In addition, essential investment structures and mechanisms have evolved. For instance, bond ETFs (Exchange-traded funds) has been projected to get to over USD 1.9 trillion by 2024. Also, ESG investments are attracting more customers with about USD 30 trillion worth of investments in asset taxonomy.

Investment admins in the complex trading structure battle to integrate real-life limitations like the volatility of customers' market and life event changes into portfolio optimization. Usually, investment managers may prefer to emulate large amounts of possible investment options and scenarios when predicting possible profits. At the moment, the cost of transaction and limitations of computation constrains the rebalancing of investment portfolios significantly (Vadlamudi, 2018). Quantum computing can help by cutting through the various intricacies and complexities of the modern-age trading world. Using the quantum computing feature of combinatorial optimization, investment managers may be able to enhance diversification of portfolios, rebalance investment portfolios to more accurate reaction to market conditions and goals of the investor (Doewes et al., 2021). It can also streamline settlement processes of trading in a more cost-beneficial way.

Risk profiling

There is constant pressure for financial service institutions to balance hedge positions and risk more effectively. They also need to conform with the regulatory frameworks be carrying out the broader span of stress tests (Ganapathy & Neogy, 2017). Derivative pricing, management of liquidity, and risk assessment can be tricky, and computations may become challenging to carry out, making it challenging to manage the risk cost on trade effectively. Currently, the Monte Carlo simulations are constrained due to the scaling of predicted error. (Monte Carol simulations are the choice option method used to examine risk impact and financial models' uncertainties. In the future, it is expected that continuous improvements of the related amendments to standards, regulatory frameworks, and directives like the Basel III and the amendments to it. Financial service providers will need a more extensive collection of risk management stress outcomes (Neogy & Paruchuri, 2014). This will result in a possible increase in the cost of compliance and penalties and remediation's in non-compliance cases by more than two folds in years to come (Rahman et al., 2020).

Due to more advanced risk profiling needs and increased obstacles from regulations, quantum computing data processing features can increase the speed of risk scenario simulations with higher accuracy while also assessing other possible results.

Benefits of quantum computing

The benefits of quantum computing to businesses and financing service providers can be drawn from the following scenarios:

- It improves gains on investment
- It reduces capital needs.
- It brings about fresh investment opportunities.
- Enhances the management and detection of risk and compliance.

OTHER POSSIBLE USES OF QUANTUM COMPUTING

Only a minimal number of computers can address actual user application needs that deliver a quantum pace or even an industrial efficient one. It is time to find a game-changing application that can handle real-world user applications (Ahmed et al., 2021a). As mentioned earlier, several companies from different industries and fields have already begun this process. They have started analyzing real-world issues which are hugely complicated that can be cracked using quantum computing processes. The combination of cloud computing with quantum computing makes it possible for the number of applications that can be found to increase significantly (Vadlamudi, 2016). With the increase in acceptance of quantum computers, more companies will begin to solve more ambitious issues using quantum computers. Quantum computing processes can be used in the following scenarios:

- In the health industry, new types of drugs may be discovered, and companies might be able to speed up the process of development of drugs in the early stages using simulation of complex compounds, interactions, and therapy.
- Vast amounts of money might be by the agricultural industry through reengineering the manufacturing process of fertilizers. This also has a positive effect on climate.
- Nations can tackle the issue of climate change by discovering more adequate means of containing and eliminating carbon and other harmful gases.
- Transport companies can optimize • routes to save money on shorter routes. According to research, USD30 million can be held by logistics companies if they can find out how a driver can cover a mile less than his normal daily distance. Once this is multiplied by the entire network, it would result in a substantial amount.
- Quantum computer manufacturers will improve the technology by using it to discover improved quantum algorithms and qubits.

Conclusion

Technology evolves and, quantum computing is the evolution of computing from the traditional method. Several issues (both computational and real-world issues) may be resolved efficiently through the deployment of quantum computers. Problems in finance and management of credit risk as well as fraud detection can be dealt with using quantum computers. There is no telling specifically when these computing systems will be able to come true on their potentials or whether a quantum computer may be able to perform all the above functions. However, the possibilities are endless with the prospects as well. The impact of quantum computers on technology and the way machines are perceived would drastically felt as more person adopt the use of quantum computers.

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