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Quantum Computing: Significant Challenge and it's to-be

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ABSTRACT

In recent years, quantum computing research has expanded in both the public and private sectors. Quantum computing is the use of computation execution to perform quantum-mechanical phenomena such as superposition and complex computation. Quantum computing began in the 1980s. Since a quantum computer is ultimately the interface between users, data, and networks, tasks that are at the forefront of traditional computing - a quantum computer may be more profitable for performing different tasks. In this paper, the applications, uses and future challenges of Quantum Computing are discussed in detail.

1. Introduction

Quantum computing began in the 1980s, when a physicist Paul Benioff proposed a quantum mechanical model of the Turing machine. Also, Richard Feynman and Yuri Manin then further say that a quantum computer has the ability to simulate things that a classical computer cannot. In 1994, Peter Shor developed a quantum algorithm to construct components of integers. This algorithm had the ability to decrypt Rivest–Shamir–Adleman (RSA) -encrypted communication. Despite ongoing experimental progress since the late 1990s, most researchers believed that "fault-tolerant quantum computing is still a distant dream" Shor, P. W. (1999). The pictorial representation of quantum computing technique is shown in Fig. 1.

Figure 1. *Quantum Computing*

In recent years, quantum computing research has expanded in both the public and private sectors. Quantum computing is the use of computation execution to perform quantum-mechanical phenomena (Svoreet al., 2018) such as superposition and complex computation. Computers that perform quantum calculations are known as quantum computers. Quantum computers are thought to be capable of solving some uncommonly complex problems, such as integer factors that reduce RSA encryption. It is capable of working much faster than classic computers. The study of quantum computing is a subfield of quantum informatics.

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2. Quantum Computer

A quantum computer is a computer that is computed mechanically. It has a new type of hardware with computational mechanism that mechanisms are based on quantum mechanics. In other words, hardware and software are built on the principles of quantum mechanics in quantum computers (Tejada, et al., 2011). The basic unit of information in a quantum computer is called a qubit. The unit is based on superposition states in which both the positions 0 and 1 are overlapped. Current computers represent information through a single bit, with only a value of 0 and 1.

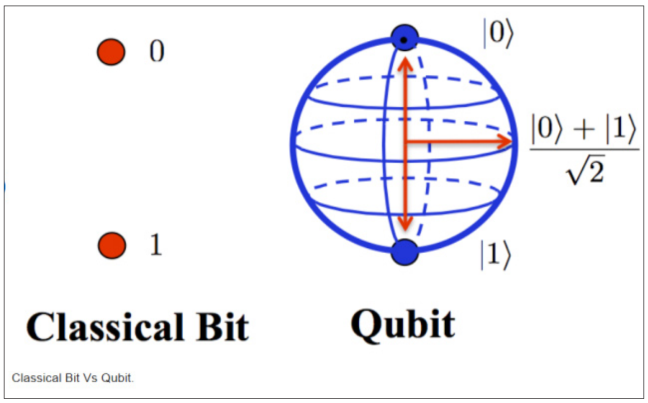

Figure 2. *Bit Representation*

In another way, quantum computers use qubits that can describe more information than bits. Therefore, if multiple numbers are given and processed in parallel between them, then quantum computers are capable of super speed calculations. As a result, quantum computers can compute some important complex problems whose solutions are considered impossible or inconsistent in traditional computers. It is generally believed that the advent of quantum computers can change computers and our lifestyles. Some have demonstrated that quantum computers can be used to calculate and solve certain problems that are faster than any classical computer (Barnett et al., 2016).

In terms of total calculation, a 4 qubit computer is 16 times more efficient than a four-bit computer. Once we learn to fully utilize their work capacity, a quantum computer, containing a few more qubits, will incidentally surpass even the world's fastest supercomputer.

Since a quantum computer is ultimately the interface between users, data, and networks, tasks that are at the forefront of traditional computing - a quantum computer may be more profitable for these tasks.

To aid in the conceptualization of the necessary hardware components in analog or gate-based quantum computers, hardware can be modelled into four layers: the "quantum data plane", where qubits are present; "Control and measurement aircraft", responsible for carrying out operations and measurements as required; "Control processor plane", which determines the order of operation and measurement required by the algorithm; And "host processor," a classical computer that handles user access to networks, large storage arrays, and user interfaces (Iwasawa et al., 2019). This host processor runs a traditional operating system / user interface, facilitating interaction between users, and a high-bandwidth connection to the control processor.

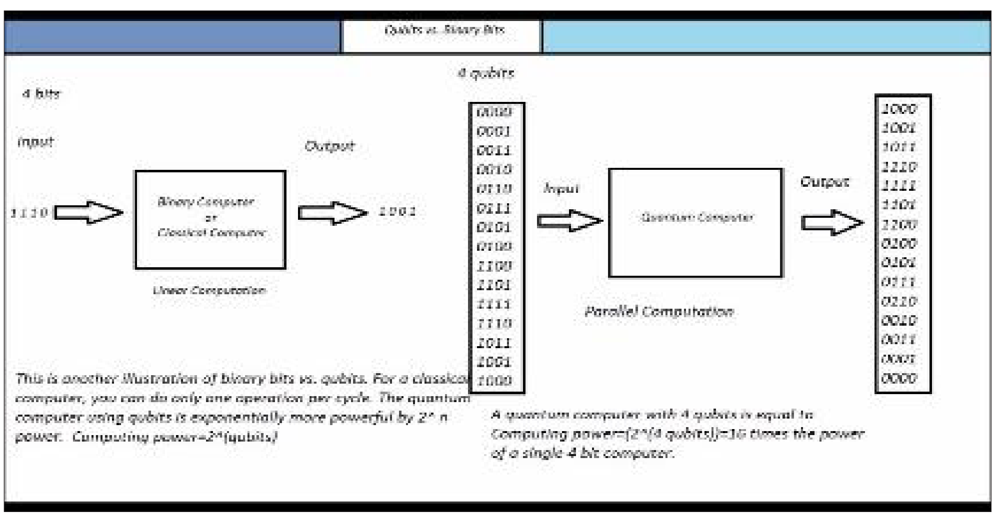

Figure 3. *Qubit Calculation Representation*

2.1. Applications of Quantum Computing to know it

Artificial intelligence (AI) is a primary application of quantum computing. Artificial intelligence is based on the theory of human intelligence which can be defined from experience and education until a computer program appears to demonstrate "intelligence" becomes more accurate as a response. In addition, quantum computing has many more applications. Some of them are briefly discussed below.

2.1.1. Artificial Intelligence

AI systems rely on a large amount of data that allows algorithms to unload, categorize, and analyse them. Quantum computers with specific characteristics can help classify that data more methodically. We can say that quantum computing-based AI algorithms can help identify patterns that are untargeted for classical computers Hassanzadeh, P. (2020).

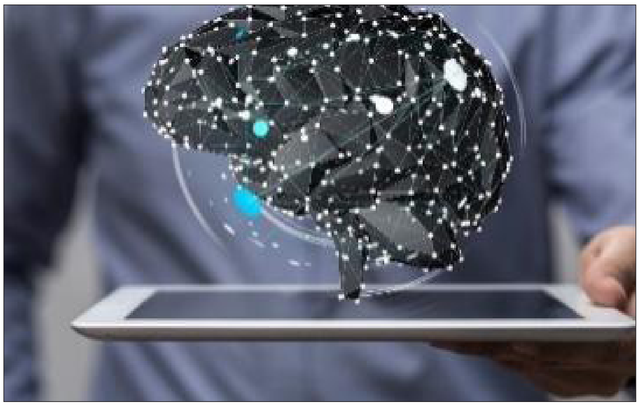

Figure 4. *Quantum Computer Based AI*

2.1.2. Cyber Security

Quantum computing is a rapidly emerging field of computer science that is extending the foundations of cyberspace. With quantum microchips, the ability to solve classical problems is now very easily solved through quantum computing. Here prime-factoring is a problem on which researchers/ software developers are working towards cracking it soon. A quantum algorithm is capable of many important task already exists for in security issues.

2.1.3. Traffic Optimization

Modern navigation software can guide a vehicle with the least route, distance and time to any destination keeping in mind the current traffic. But in this calculation he cannot take into consideration the path performance options of other vehicles. So when a system tells vehicles to change the route again, it creates another path of the route by directing wider traffic through the choke points.

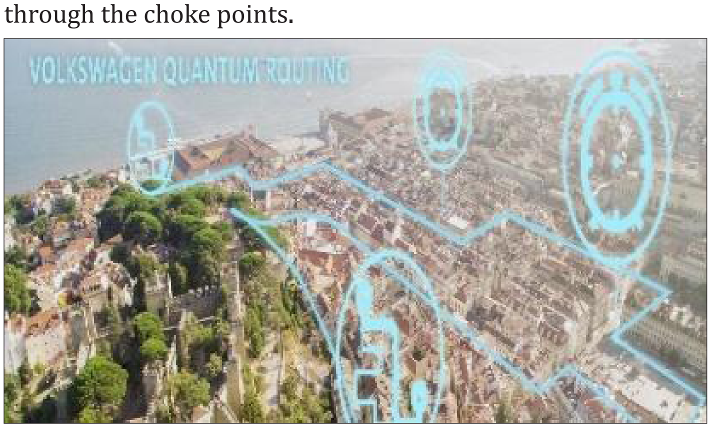

Figure 5. *Volkswagen Quantum Routing*

Volkswagen has established the world's first live use of quantum computing to help improve traffic routing. During the experiment, nine public transport buses used a TMS developed by Volkswagen scientists in the USA and Germany, powered by a D-Wave quantum computer to estimate the fastest travel ways separately and in near-real-time.

2.1.3. Drug Development

Quantum computing has advanced rapidly over the years due to the substantial development of both hardware and algorithms. These advances are moving quantum computers closer to their overall commercial utility.

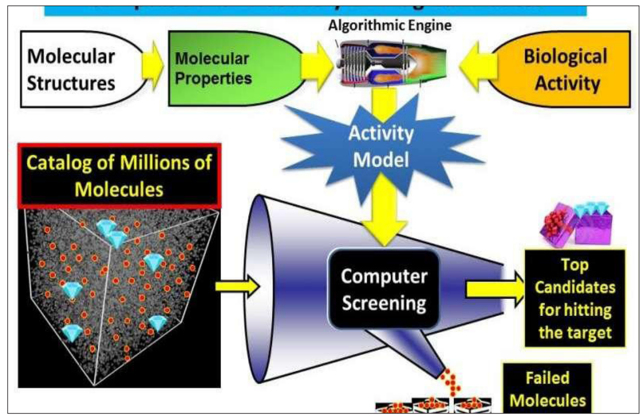

Figure 6. *QC based Drug Development*

Drug discovery is a promising area of application that will explore many uses for these new machines (Kitchen et al., 2004).

Quantum computers are a powerful tool for studying complex systems such as human psychology, and for determining the effect of drugs on biological systems and living organisms. Quantum computing has many uses in pharmacological research and development, especially in the early stages of drug discovery and development.

2.1.4. Weather Forecasting and Climate Capture

Several variables are involved to predict the weather, such as temperature, air pressure, and air density, which makes it difficult to predict accurately. The application of quantum machine learning helps improve weather pattern recognition. It makes easier for scientists to forecast hazardous weather events and possibly save thousands of lives.

Meteorologists are also able to produce and determine more detailed climate models using quantum computers, which offer better insight into ways to moderate climate variation and its negative effects (Bellenger et al., 2014). Including the above there are many other applications of quantum computing such as Cleaner Fertilization, Financial Modelling, Solar Capture, Better Batteries, Electronic Materials Discovery etc.

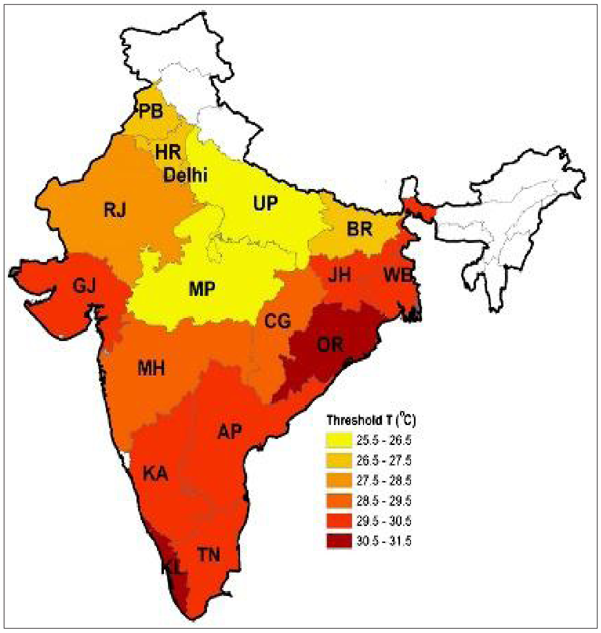

Figure 7. *Weather Pattern Recognition by QC*

2.2. Top Countries and Companies in the Field of Quantum Computing

Many companies are pushing to build quantum computers, including Intel and Microsoft in addition to Google and IBM. These companies are trying to build hardware that replicates the circuit model of classical computers. However, current experimental systems have less than 100 qubits.

IBM is a pioneer in the field of quantum computing. In January 2019, IBM unveiled IBM Q System One, the world's first integrated universal predictive quantum computing system. It is designed for scientific and commercial use. IBM Quantum is the first initiative to create a universal quantum computer for industry, engineering and science (Ding et al., 2020). This effort involves advancing the entire quantum computing technology stack, exploring applications to make quantum widely usable and accessible.

Several nation states are successively in the competition of foremost the world with the expertise of quantum computing. According to market reports, the global Quantum Computing market accounted for US$88.1 billion in 2019 growing at a CAGR of 29.1 percent during the forecast period of 2019 to 2026 (Ding et al., 2020). In this competition of leading the world in quantum computing technology the following 10 countries are as:

Table1. *Top 10 Countries Using QC Technology*

Country	Investment on Quantum Technologies
US	US$ 1.2 billion
Canada	US$ 1 billion
Germany	650 million Euros
France	€40 million
UK	US$440 million
Netherlands	€135 million
Russia	US$3 billion
China	
South Korea	US$40 million
Japan	US$270 million

Many concerns worldwide are demanding in emerging quantum computing or quantum communication. Quantum computing and communication are two streams of quantum informatics, which designate and depict informatics in the framework of quantum physics. Few of them are as given below:

Table 2. *Top Companies Using QC Technology*

Company	Technology Used
Airbus	Algorithms
Alice & Bob	Superconducting
Amber Flux	Quantum Programming, Optimization, Algorithms, Quantum Financial Services
Atos	Quantum Programming, Classical Simulation, Cryptography
Cogni Frame Inc	Quantum Algorithms Quantum for financial services
D-Wave	Superconducting Quantum Annealer
Fujitsu	Quantum Dots
Google QuAI	Superconducting
Honeywell	Trapped Ion
IBM	Superconducting
HP	Algorithms, NMR
Microsoft Research QuArC	Algorithms

2.3 Goals and Future of Quantum Computing

The challenges of building a quantum computer are huge and can be separated into physics and engineering challenges. The challenges of physics are primarily to provide consistent timing of the output bit in the superposition state and to increase the accuracy of the qubit in the tangled state and to define ways to compensate for errors that occur during quantum operations. The engineering challenge can be summarized by the term 'scalability'. Quantum computing allows data to be performed computationally very quickly and efficiently by taking advantage of quantum symmetry. With this, a large amount of data could be stored here, using the principle of superposition.

According to Quantum Computing Strategies : 2019, a new report from Inside Quantum Technology, the market for quantum computing will reach $780 million by 2025, going on to reach $2.6 billion by 2029.

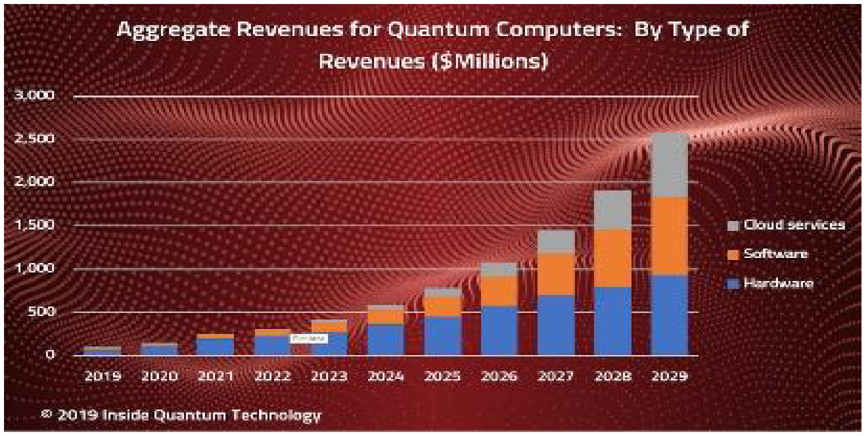

Figure 8. *Aggregate Revenues for QC*

Also the Global quantum computing 10 year market forecast is given below according to the different industries.

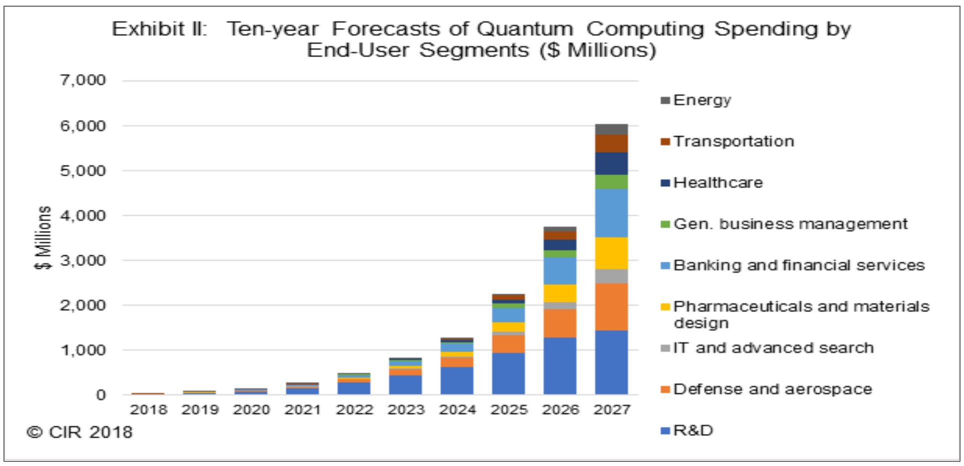

Figure 9. *Global QC 10 year Forecast*

3. Conclusion

Quantum computing is the new field of science which uses quantum phenomena to perform operations on data. The goal of quantum computing is to find algorithms that are considerably faster than classical algorithms solving the same problem. Quantum computing offers a path forward by taking advantage of quantum mechanical properties. So, the rapid progress of computer science led to a corresponding evolution of computation from classical computation to quantum computation. The quantum promise is still a long way from achieving practical realization. The properties of quantum mechanics that enable quantum computers superior performance also make the design of quantum algorithms and the construction of functional hardware extremely difficult.

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