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The Review on Quantum Computers and Their Application in Future Era

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***Abstract*: - Quantum computing has become a hot topic in recent years. It provides high consumption and exponential speed over classical computers by controlling the behaviour of small physical objects i.e., microscopic particles like atoms, electrons, photons, etc. Quantum computing is an emerging technology. The clock frequency of current computer processor systems may reach about 40 GHz within the next 10 years. By then, one atom may represent one bit. Electrons under such conditions are no longer described by classical physics, and a new model of the computer may be necessary by that time. The quantum computer is one proposal that may have merit in dealing with the problems presented. Currently, there exist some algorithms utilizing the advantage of quantum computers. For example, Shor's algorithm performs factoring of a large integer in polynomial time, whereas classical factoring algorithms can do it in exponential time. In this paper, we will briefly explain quantum computers, their history, the difference between classical computers and Quantum computers, and the challenges they faced Lastly, we conclude with its future scope.**

Keywords: - Qubits, Quantum Gates, Superposition, Cryptography, Shor's algorithm

I. INTRODUCTION

Computers that use quantum mechanics as their foundation are known as quantum computers. In contrast to traditional computers, which only allow bits (0 and 1) to be in one state at a time, these computers do computation using qubits, which may be in several states simultaneously. Due to this characteristic, quantum computers are able to tackle those challenging mathematical problems in exponentially less time than classical computers. Quantum computers have a million times the greater computational capacity than supercomputers as a result. The main characteristics of quantum computers were three.

A novel form of computation called quantum computing, which is based on quantum physics, deals with the physical world's stochastic and erratic character. Because quantum mechanics is a more comprehensive model of physics than classical mechanics, quantum computing is a more comprehensive model of computing and has a greater potential to address issues that conventional computing cannot address. Unlike conventional classical computers that are based on classical computing and employ binary bits 0 and 1, they store and modify information using their own quantum bits, commonly known as "Qubits." Quantum Computers are the term for the computers that use this kind of computing. Transistors, logic gates, and integrated circuit circuits cannot be used in such tiny computers.

As a result, it employs bits made of subatomic particles such as atoms, electrons, photons, and ions together with information on their spins and states. They are more powerful because they may be superimposed and operated in parallel while effectively utilizing memory. The Church-Turing theorem can only be disregarded by quantum computing, which makes quantum computers operate orders of magnitude faster than conventional computers.

II. CURRENT APPROACHES TO QUANTUM COMPUTERS

This section examines the construction of such a quantum computer. For the construction of a quantum computer, there are five experimental prerequisites [8, 9]. The capacity to reliably represent quantum information is the first prerequisite. 229 A physical qubit system will have a finite number of accessible states since a qubit is a straightforward two-level system. Examples include the ground and first excited states of an atom, the vertical and horizontal polarisation of a single photon, the spin states of a spin 1/2 particle, and others. Second, the capacity to choose a fiducial beginning state is necessary for a quantum computer.

Because of the imperfect isolation from their surroundings and the challenge of accurately manufacturing desired input states, this poses a serious issue for most physical quantum systems. Third, compared to the gate operation time, a quantum computer requires lengthy decoherence durations. Decoherence is the connection of a qubit with its surroundings, which causes the quantum phase coherence to be lost. The coherence-related quantum mechanical quality, such as superposition and entanglement, can no longer be detected after decoherence. The capacity to measure output outcomes from individual qubits is the fourth prerequisite. A quantum superposition is often the result of a quantum algorithm.

Consequently, it is essential to accurately read out a result from the quantum state utilizing the classical system. The capacity to create a universal set of quantum gates is the sixth need. A quantum computer, like a classical computer, contains universal gates that can carry out any legal quantum computation. DiVincenzo established that two-qubit gates operating simultaneously are sufficient to create a generic quantum circuit [10]. We can construct any multiple qubit logic gates using a two-qubit controlled-NOT gate and a single qubit gate. Additionally, after we develop a two-qubit controlled-NOT gate, we may combine these gates to create a quantum computer.

III. MERITS OF QUANTUM COMPUTERS

1. Quantum computers execute computation exponentially quicker than conventional computers due to a feature known as quantum entanglement.
2. Parallel computing on quantum computers uses a phenomenon known as quantum tunneling, which reduces the amount of electricity consumed by 100 to 1000 times when compared to traditional computers.
3. Compared to conventional computers, quantum computers are 1000 times more effective, dependable, and quick.

4. Unlike classical computers, quantum computers were kept at temperatures below zero degrees Celsius so they could tackle difficult problems quickly and efficiently without overheating.
5. In contrast to conventional computers, quantum computers use entanglement to solve optimization issues by selecting the optimum route out of all feasible options. Like chess, they can perform about a trillion moves per second. It will also be possible to crack the cryptographically encoded security because of quantum mechanical features.
6. By creating new pharmaceuticals, it will advance various businesses, including the pharmaceutical and petroleum industries. It will also significantly alter the fields of data mining and artificial intelligence.

III.I QUANTUM COMPUTING SYSTEM

- Superposition, a type of quantum mechanical phenomenon, is used in quantum computing to conduct operations on data. In conventional classical computing, information is represented as classical information, with bits precisely assigned the values of zero or one. A traditional two-bit system, for instance, has four states: 00, 01, 10, and 11.
- The two bits that make up the state's particular definition can be used to define any one of the four possible states theoretical representation of such computers is known as a quantum Turing machine or universal quantum computer.
- To use quantum computers effectively, new algorithms must be created. These algorithms, also known as quantum algorithms, use quantum logic gates to incrementally calculate data in a manner like circuit diagrams.
- The detector hits are first divided into doublets and then triplets by the algorithm. The objective is to determine which triplet pairings may be merged to generate quadruplets by building a QUBO from the triplets. Paul Benioff imagined the idea of a quantum touring machine, or the hypothetical notion of a quantum computer, in 1980. (Benioff, 1980). Richard Feynman proposed the efficient modeling of quantum systems as the initial use case for a quantum computer in 1982. (Feynman, 1982).
- Quantum Machine Learning (QML) is a potential early application in the NISQ era because of recent advancements in quantum computing architecture and techniques. Information theory aspects of quantum learning, such as its complexity, accuracy, and asymptotic behaviour in a fault-tolerant regime, as well as more immediate aspects like data encoding, learning circuit models, and hybrid architectures with classical calculations are just a few examples of the broad range of research topics that are covered by QML. In a few examples of HEP investigations, QML has been used experimentally for data processing and event reconstruction. In terms of maturity and application, they may be divided into two categories based on quantum annealing and quantum circuit models, each of which has advantages and limitations.

Difference Between Classical and Quantum Computers

Quantum Computers	Classical Computers
They perform computing by using quantum bits or qubits.	They perform computing by using binary bits.
Qubits need to be isolated from the environment and have too kept at a temperature which is below 0 degrees Celsius.	Binary bits were needed to be kept in isolation, they can easily keep or work at room temperature.
The computing speed of a Quantum computer is much higher than that of a classical computer.	The computing speed of the classical computer is lower than a quantum computer.
Qubits can be at all the possible 4 states at the same time.	Binary bits of classical computers can only be in 1 state at a time.
Copy if qubits from one state to another are almost impossible.	Copy of binary bits from one state to another is possible and even easy too.
Information gets processed in Quantum circuits or Quantum logic gates in a parallel manner.	Information gets processed in classical computers sequentially.
Backtracking is possible.	Backtracking is not possible.
The Quantum computer was based on quantum mechanics and its properties like superposition interference and Entanglement.	The classical computer was not based on quantum mechanics and its properties.
Data teleportation is possible because of quantum entanglement.	In a classical computer, data teleportation is not possible.
Quantum computers perform their computing in a parallel way because it has both waves as well as particle nature	Classical computers have only particle nature therefore they perform computing sequentially.

IV. FUTURE SCOPE

1. Develop new algorithms that will work on noise and aid in purging it from quantum computers, making them noise-free.
2. Teleporting of data and information has already been accomplished, but objects still need to be transported.

3. Rather than destroying their current related Securities, quantum computers can work in the realm of cryptographic security by creating more secure networks for the government, military, banks, etc.

Before a useful quantum computer is launched, there is still more work to be done. Future improvements are required in various areas.

Future requirements include enabling a Quantum Error Correction algorithm that has low overhead and lowers qubit error rates, creating more algorithms for problem-solving that use fewer qubits, reducing circuit thickness so that NISQ computers can operate, improving techniques for verifying, debugging, and simulating quantum computers, and scaling the number of qubits per processor in a way that keeps or can improves error rates.

Future quantum computers are projected to take all feasible operations and randomly spit them into games owing to their quantum features like super positioning and qubit entanglement, which would lead to unexpected circumstances and outcomes for players. It will be an endless journey.

Quantum computing on the cloud has the potential to supplant commercial endeavors like other cutting-edge technologies like artificial intelligence and cryptography. The memory needed should also be large enough to provide an environment for application development and testing for multiple developers to simulate quantum computers using suitable shared memory since the classical simulation of fifty qubits is equal to the memory of one petabyte that doubles with every single qubit added.

Problems with AI and machine learning may be resolved in a realistic period that may be lowered from millions of years to a few seconds. Many quantum algorithms, including Grover's algorithm for searching and Shor's algorithm for factoring big numbers, have been created. Soon, more quantum algorithms will be released. Google has also stated that it will create a functional quantum computer with a 50-qubit quantum computer over the next five years and will achieve quantum supremacy. IBM will soon start selling quantum computers.

The development of quantum computers depends on a variety of variables. Commercial NISQ application development may be assisted by money and interest from the private sector.

It is based on the development of quantum algorithms, the amount of government funding available for the field of quantum technology, and the sharing of ideas among researchers, scientists, and engineers. A defensive result is also helpful in highlighting the limitations of quantum technology. It can assist in overcoming those unfavourable findings that may result in a new discovery.

V. CONCLUSION

The ideas, algorithms, and hardware considerations for quantum computing have been addressed in this article. Using various resources, several research teams are examining qubits and quantum 231 logic circuits (i.e., atom, ion, electron, and photon, among others). Before Moore's law runs out of room for development using the classical computer paradigm, it is anticipated that a workable quantum computer will be realized. Currently, a quantum computer that can factor 15 is based on seven-bit NMR. It is necessary to conduct more studies, for instance, through simulation, on quantum computers that use conventional processors. A simulator of this kind must be capable of handling quantum computers that use a significant number of qubits.

To do this, we must use massively parallel processing techniques to obtain more insightful findings in a realistic amount of time. The research process might be sped up by using hardware abstraction and other conventional computer principles on quantum computers. As an illustration, several organizations suggested quantum programming languages that enable us to conceptualize quantum computer operations in the same way as we do with conventional computers. Quantum computer realization efforts have just started. Without a doubt, we need to do a more thorough study of the physical reality of quantum computer components. To improve the state of the art for quantum computers, computer scientists and engineers will need to consider both the numerous architectural options for quantum computers and the various novel (practical) quantum algorithms.

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