

# Quantum Computing Architectural Advancements and it's Challenges

Suyeta Saha<sup>1</sup>, Suman Roy<sup>2</sup>, Anirban Bhar<sup>3</sup>, Dhriti Chakraborty<sup>4</sup>

<sup>1</sup>(B. Tech Student, Department of Information Technology, Narula Institute of Technology, Kolkata, India  
Email: suyetasaha2004@gmail.com)

<sup>2</sup> (B. Tech Student, Department of Information Technology, Narula Institute of Technology, Kolkata, India  
Email: sumanroy2000suman@gmail.com)

<sup>3</sup> (Assistant Professor, Department of Information Technology, Narula Institute of Technology, Kolkata, India  
Email: anirban.bhar@nit.ac.in)

<sup>4</sup> (Assistant Professor, Department of Information Technology, Narula Institute of Technology, Kolkata, India  
Email: dhriti.chakraborty@nit.ac.in)

## Abstract:

In this modern-day computing technology is another way to derive all the calculations and programs in more efficient way. Quantum computing is computational framework which is based on quantum mechanism. Quantum computers are used to describe the mechanical phenomena such as entanglement, superposition, annealing, and tunneling to solve problems which normal human being can't solve in their lifetime. In this work we will compare the classical computers with the quantum computers. However, utilizing the power of quantum computers in real-life application will develop the concept of quantum mechanics in the field of computer science and technology. Keeping in mind, quantum computing aims to explores the future and existing projects in detail. This quantum computing concept we can use in various type of field such as cryptography, machine learning, medical research, drug revolution and etc. They also address a variety of situations that are encountered in real life, such as risk assessment, logistics, and satellite communication.

*Keywords* — **Quantum computing, Privacy, Cryptography, Machine learning, Risk assessment.**

## I. INTRODUCTION

These are the basic ideas of quantum computation which introduced by a brief discussion of Bennett (1973, 1982) and Friskin's (1982, 1997) ideas of reversible computation. Quantum computers, generally, utilize the quantum mechanical phenomena of superposition and entanglement to create states that scale exponentially with the number of qubits or quantum bits. Classical computers that use the binary bit, quantum computers use qubits that are produced by the quantum state of the object to perform operations. The tight correlation that exists between quantum

particles is known as entanglement. The quantum computer is able to operate with 0 and 1 thanks to these phenomena. The superposition of 0&1 giving them the advantage in doing complex calculations that modern classical systems cannot do or would take a significant amount of time to get the desired result. Currently, quantum computing is the metaphorical elephant in the room for researchers just because of it's potential for solving the complex problems. There is an increasing threat to the security of our data. Many cryptography systems rely on the complexity of the mathematical problems for their security [1]. However, since the advent of quantum computations, cryptography is at

a significant threat. According to IBM, it is the goal of them to make 433-qubits in 2023 [2].

The main aim of writing this review is to provide a general understanding of quantum computing with its application and the essence of quantum entanglement. This paper is organized as follows. Section 2 describes the entanglement used using several databases. In section 3, cryptography concept will be discussed in detail with proper application. In section 4, there will be discussed the various type of uses of the quantum computing in our real life. And lastly in section 5, is dedicated to the conclusion of the article.

## **II. QUANTUM ENTANGLEMENT**

Quantum entanglement is known as a phenomenon that occurs when a group of particles are released or share some spatial proximity so that the quantum state of each particle of the group cannot be described independently [3]. Quantum entanglement involves the cutting-edge technology and will bring great benefits to society. Entangled systems need special preparation which is specified by the Pauli exclusion principle, has to be created, with the actual spin of each particle remaining in a state of quantum uncertainty [4]. Einstein believed that everything in the world exists independently of us and that no signals carrying information could travel faster than the velocity of light. However, the numerous quantum experiments over many decades had proven him wrong. The phenomenon of quantum entanglement does take place, and entangled particles do give the impression of being able to "communicate" with one another across vast distances at a rate that is greater than the speed of light.

The theory of entanglement can be put to use in the real world in the form of practical applications in quantum information processing, such as quantum cryptography and quantum computing. Quantum computers use quantum bits (qubits) that are entangled with one another to conduct specific tasks significantly more effectively than classical computers can.

## **III. CRYPTOGRAPHY**

One of the most useful fields is cryptography in quantum computing. The application of the principles of quantum physics in the context of cryptography, also known as quantum encryption, allows for the secure encryption and decryption of sensitive information. Quantum cryptography is the science of exploiting quantum mechanical properties to perform cryptographic tasks. The best-known example of quantum cryptography is quantum key distribution which offers an information-theoretically secure solution to the key exchange problem [5]. The algorithm developed by Shor is comparable to the hidden subgroup problem (HSP), which applies to finite Abelian groups.

Quantum computing theory is based on simple fundamental and unchanging principles of quantum mechanics [6]. Charles H. Bennet and Gilles Brassard developed the concept of quantum cryptography in 1984 as part of a study between physics and information [2]. Cryptography theory provides an answer or solution to the assumptions base problems like larger integer factorization problem which makes an impact on development of a system.

## **IV. QUANTUM COMPLEXITY**

Complexity is the study of algorithm. There is "Universality" which makes it possible for computer scientists to classify the algorithms in different types of complexity. Now a days we can analyse an algo by Turing machine with a great speed of efficiency. Since the computational work needs the factorization of N numbers growth exponentially. The fact that Shor's algorithm, when executed on a quantum computer, was able to solve the factorization problem in polynomial time was the most important implication of his findings. RSA129 might be factored in a matter of seconds by a quantum computer operating at 100 MHz and employing the approach developed by Shor. In its most basic form, the necessity of the complexity idea can be understood by considering speed and efficiency.

In addition, it is not evident how to carry out the simulation in a manner that is more effective. That's why we need to re-examine the complexity

theory and study about the computational study about the computing based devised.

## **V. APPLICATIONS OF QUANTUM THEORY**

Due to its capability of carrying out complicated computations at rates that are inconceivable with classical computers, quantum computing possesses the potential to bring about a revolution in a variety of different sectors. In spite of the fact that quantum computing is still in its infancy stage, researchers and scientists are investigating a variety of potential applications across a variety of industries. The following is a list of potentially fruitful areas where the application of quantum computing could have a big impact:

### *A. Quantum computing in cloud:*

Cloud-based quantum computing services have been introduced and used in several backgrounds. We have used this in the purpose of games, research and a lot of tech related fields. This provides a path to quantum computing, a quantum computing platform that anyone can access publicly in a cloud environment setting [7]. It is accessible to users around the globe to execute real quantum processing tasks. cloud computing is a technology which gives varicosity in the field of modern data and architecture technology [2].

### *B. Security:*

Now a days, data security is so much essential for protecting databases, critical information and also important files. Quantum computing takes an important part to protect our personal and critical information. The field of cybersecurity has become increasingly significant due to the reliance on computer systems and technology advancements. Cybersecurity experts use cryptography to design algorithms and other measures to protect the data [2].

Cryptography is another process to protect information from unauthorized access. The method of encrypting and decrypting is called cryptosystem (or cypher system), while the information used is called a key.

### *C. Industries:*

Quantum computing will revolutionize numerous industries in the future. According to Dilmegani (2021), IBM predicted that quantum computing would evolve over three horizons in the industrial revolution [8]. Quantum computing technology can significantly impact various industries. Quantum Computing promises to solve high-value, classically intractable computational problems in the domains of optimization, machine learning, and simulation across all industry sectors [9].

### *D. Drug development:*

In the last decades, computational approaches started to play an increasingly large role in research and development. By exploiting their quantum mechanical properties, quantum computers have been proposed to simulate quantum systems efficiently. Most current efforts in quantum computing are finding the most challenging algorithms to explore new developments.

A quantum computer can perform such calculations in polynomial time without making any uncontrolled ap-proximations if the initial state is close to the ground state [10]. Still now the hardware and the algorithm of quantum computing needs highly progress to increase development in this field.

### *E. Financial modelling:*

In the financial services industry, there are many computationally challenging problems arising in applications across asset management, investment banking and retail & corporate banking. Quantum computing holds the promise to solve the solutioning problems in the financial modelling field. IBM pursued quantum computing hardware to involve superconducting in Quantum computing. A metric that has been proposed and employed by IBM to measure progress in development in quantum computing is Quantum Volume. The digital financial services revolution is full blast disrupting the industry and opening the door to new players threatening the current status quo [11] which are increasing their development level.

These applications highlight the enormous impact that quantum theory has had on a variety of

scientific and technological fields; furthermore, continuing research and advances are continually expanding the possible applications of quantum theory.

## **VI. INTERNAL APPLICATION AREAS**

The quantum theory, which is sometimes referred to as quantum mechanics, is a fundamental theory in the field of physics that describes the behaviour of matter and energy at the lowest scales. This includes the behaviour of subatomic particles such as electrons and photons. Quantum theory is most commonly linked with the study of physics; however, the principles and ideas underlying this theory have applications in a wide variety of other fields and fields of study.

### **A. Search and graph:**

The fact that a qubit can theoretically represent an infinite number of states allows for solving complex combinatorial optimization problems, which is currently one of the major application areas for current quantum computing technologies. such as the solution of D-Wave (Johnson et al., 2011). Combinatorial optimization is the process where it's finding one or more optimal solutions to a problem. The set of possible solutions can be defended with several constraints and the goal is to optimize the objective function with the best solution. Respectively, quantum computers are expected to play a decisive role in the financial services industry.

### **B. Algebraic:**

The ability of quantum computing to accelerate optimization problems plays a crucial role for narrow AI approaches. Quantum computing's theory can help to evaluate problems regarding architectures and weights for machine learning and artificial intelligence. Quantum computers offer several approaches to solving problems like this, thereby, again, accelerating calculation and allowing for more complex network architectures.

## **VII. CONCLUSION**

After demonstrating the whole applications and the features of quantum computation the concept of quantum computation is clear. In this review entanglement, cryptography concept discussed which basically aims the application of the quantum computing concept. Quantum simulations will continue to attract researchers in quantum computations for several years, because of its wide possibilities. Novel and practical use cases for existing quantum algorithms is a useful future research direction. In this article, the basic info about the quantum computing is totally announced on the basis of it's application. Also, we have focused on the development and modification on this modern tech fields by using quantum techniques. Considering the limits and features quantum computing.

## **REFERENCES**

- [1] Hey, T. (1999). Quantum computing: an introduction. *Computing & Control Engineering Journal*, 10(3), 105-112.
- [2] Zhahir, A. A., Mohd, S. M., Shuhud, M. I. M., Idrus, B., Zainuddin, H., Jan, N. M., & Wahiddin, M. R. (2022). Quantum Computing and Its Application. *International Journal of Advanced Research in Technology and Innovation*.
- [3] Romero, J., Leach, J., Jack, B., Dennis, M. R., Franke-Arnold, S., Barnett, S. M., & Padgett, M. J. (2011). Entangled optical vortex links. *Physical review letters*, 106(10), 100407.
- [4] Wong, B. (2014). On quantum entanglement. *Quantum Inform*, 81(2), 865-942.
- [5] Hassija, V., Chamola, V., Saxena, V., Chanana, V., Parashari, P., Mumtaz, S., & Guizani, M. (2020). Present landscape of quantum computing. *IET Quantum Communication*, 1(2), 42-48.
- [6] Ansari, H., Parameswaran, A., Antani, L., Aditya, B., Taly, A., & Kumar, L. (2006). Quantum cryptography and quantum computation. IIT, Bombay, 98.
- [7] Soeparno, H., & Perbangsa, A. S. (2021). Cloud quantum computing concept and

- development: A systematic literature review. *Procedia Computer Science*, 179, 944-954.
- [8] Bayerstadler, A., Becquin, G., Binder, J., Botter, T., Ehm, H., Ehmer, T., ... & Winter, F. (2021). Industry quantum computing applications. *EPJ Quantum Technology*, 8(1), 25.
- [9] Santagati, R., Aspuru-Guzik, A., Babbush, R., Degroote, M., Gonzalez, L., Kyoseva, E., ... & Utschig-Utschig, C. (2023). Drug design on quantum computers. arXiv preprint arXiv:2301.04114.
- [10] Egger, D. J., Gambella, C., Marecek, J., McFaddin, S., Mevissen, M., Raymond, R., ... & Yndurain, E. (2020). Quantum computing for finance: State-of-the-art and future prospects. *IEEE Transactions on Quantum Engineering*, 1, 1-24.
- [11] Rietsche, R., Dremel, C., Bosch, S., Steinacker, L., Meckel, M., & Leimeister, J. M. (2022). Quantum computing. *Electronic Markets*, 32(4), 2525-2536.