International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Quantum Computing: Revolutionizing Technology and Cryptography for the Future

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***Abstract*—:**

Quantum computing leverages quantum mechanics to perform computations far beyond classical systems. This paper explores its foundational concepts and highlights its transformative impact, especially in cryptography, optimization, and AI.

I. INTRODUCTION Quantum computing is a groundbreaking technology with the potential to revolutionize various industries by harnessing the principles of quantum mechanics. Unlike classical computers, which use binary bits to process information, quantum computers utilize quantum bits or qubits. Qubits can exist in multiple states simultaneously thanks to superposition and can be entangled, meaning the state of one qubit is directly related to another, regardless of distance. These properties allow quantum computers to solve complex problems much more efficiently than traditional systems.

This paper focuses on the profound impact quantum computing is expected to have on technology, with a particular emphasis on cryptography. Quantum computers possess the ability to solve intricate mathematical problems at speeds that are orders of magnitude faster than classical computers. This capability has significant implications for cybersecurity, as traditional encryption methods like RSA could be broken by quantum algorithms such as Shor's algorithm. Additionally, quantum computing is poised to transform various fields like optimization, artificial intelligence, and drug discovery.

II.FUNDAMENTALS OF QUANTUM COMPUTING

Quantum computing is based on the principles of quantum mechanics, which govern the behavior of particles at the smallest scales. Unlike classical computers that use binary bits (0 or 1), quantum computers use quantum bits or qubits. Qubits have the unique ability to exist in multiple states simultaneously due to superposition. Furthermore, quantum entanglement allows qubits to be interconnected such that the state of one affects the state of another, even at great distances.

III. QUANTUM VS CLASSICAL COMPUTING

Classical computing relies on binary systems, using bits that are either 0 or 1 to represent information. In contrast, quantum computing uses qubits, which can represent both 0 and 1 simultaneously due to the principle of superposition. This allows quantum computers to perform multiple calculations at once, significantly enhancing computational power.

Moreover, quantum computers utilize entanglement to link qubits in ways that classical systems cannot replicate. This capability enables faster and more efficient problem-solving, particularly in fields requiring vast parallel processing.

IV. HOW QUANTUM COMPUTERS WORK

Quantum computers operate using qubits, which differ from classical bits in their ability to exist in multiple states simultaneously. These systems use **quantum gates** to manipulate qubits, similar to how classical computers use logic gates. However, quantum gates follow the laws of quantum mechanics and enable more complex transformations.

Quantum circuits are constructed using sequences of these gates, allowing quantum computers to perform operations that would take classical computers significantly longer. The combination of superposition, entanglement, and quantum gate operations enables quantum machines to tackle specialized tasks efficiently.

VI. Applications of Quantum Computing

Quantum computing relies on several fundamental principles that distinguish it from classical computation:

- **Superposition**: Qubits can exist in a combination of 0 and 1 states simultaneously, allowing quantum computers to evaluate multiple possibilities at once.
- **Entanglement**: When qubits are entangled, the state of one instantly influences the state of another, no matter the distance. This enables secure communication and faster computations.
- **Quantum Tunneling**: Particles can pass through energy barriers that would be impossible in classical systems. Quantum tunneling allows for exploring multiple solution paths concurrently.
- **Quantum Interference**: Algorithms use interference to amplify correct outcomes while canceling out wrong ones, improving the accuracy of results.

VII. DIFFERENCE BETWEEN CLASSICAL AND QUANTUM

Classical Computing:

- Uses **bits** (0 or 1).
- Processes one state at a time (sequential).
- Uses traditional logic gates like AND, OR, NOT.
- Works well for general-purpose tasks.
- Slower for very complex problems.
- Stable and widely used.
- Encryption is secure for now but vulnerable to quantum attacks.

Quantum Computing:

- Uses **qubits** (can be 0, 1, or both at once).
- Can process multiple states at the same time (parallelism).
- Uses quantum gates like X, H, and CNOT.
- Ideal for solving complex problems like factoring large numbers or simulating molecules.
- Much faster for specific problems.
- Still in early development and requires special conditions.
- Can break current encryption but also create quantum-safe encryption.

VIII. APPLICATIONS OF QUANTUM COMPUTING

Cryptography: Quantum computing could break current encryption methods but also enable more secure systems like Quantum Key Distribution (QKD).

AI and Machine Learning: It can speed up data processing, enhance optimization, and improve machine learning algorithms.

Drug Discovery: Quantum computers can model molecules, accelerating drug development and disease research.

Optimization: Quantum algorithms can solve complex optimization problems in logistics, finance, and manufacturing.

Material Science: Quantum simulations can help discover new materials for energy and technology applications.

Financial Modeling: Quantum computing can improve financial predictions and risk assessments.

IX. CONCLUSION

Quantum computing promises transformative advancements in fields like **cryptography**, **artificial intelligence**, and **drug discovery**.
It leverages the unique properties of qubits, such as **superposition** and **entanglement**, to process information in powerful new ways.
Unlike classical computers, quantum systems can explore many possible solutions at once, offering massive speedups for certain problems.
This makes them ideal for solving tasks that are currently impossible or take too long using traditional computing methods.
In cryptography, quantum algorithms could break widely-used encryption, urging the need for quantum-safe alternatives.
In healthcare, they can simulate complex molecules, speeding up drug discovery and personalized medicine.
AI models can be trained faster and optimized more efficiently with quantum-enhanced algorithms.
However, quantum computing still faces major hurdles, including **high error rates**, **scalability issues**, and **hardware complexity**.
Massive investments and cutting-edge research are underway globally to address these limitations.
With sustained progress, quantum computing could soon reshape entire industries and redefine what's computationally possible.

REFERENCES

[1] K. Hangle, Quantum Computing: An Overview, Wiley, 2021.
[2] J. Preskill, "Quantum Computing in the NISQ era and beyond," Quantum, vol. 2, p. 79, 2018.
[3] M. Gambetta, J. M. Chow, and M. Steffen, "Building logical qubits in a superconducting quantum computing system," Nature Physics, vol. 13, no. 2, pp. 146–150, 2017.
[4] A. Montanaro, "Quantum algorithms: an overview," npj Quantum Information, vol. 2, Article 15023, 2016.
[5] F. Arute, et al., "Quantum supremacy using a programmable superconducting processor," Nature, vol. 574, no. 7779, pp. 505–510, 2019.
[6] M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 2010.
[7] L. K. Grover, "A fast quantum mechanical algorithm for database search," in Proc. 28th Annual ACM Symposium on Theory of Computing (STOC), pp. 212–219, 1996.

[8] P. W. Shor, "Algorithms for quantum computation: Discrete logarithms and factoring," in Proc. 35th Annual Symposium on Foundations of Computer Science (FOCS), pp. 124–134, 1994.