

Toward a Unified Theoretical and Practical Framework for Quantum Computing and Quantum Enabled Cloud Architectures

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Received: 18th Dec 2025 | Received Revised Version: 30th Dec 2025 | Accepted: 03th Jan 2026 | Published: 10th Jan 2026

Volume 02 Issue 01 2026 | Crossref DOI: 10.64917/ajcsqt/V02I01-002

Abstract

Quantum computing has evolved from a largely theoretical construct into an emerging technological paradigm with profound implications for computation, information processing, and digital infrastructure. This article presents a comprehensive and integrated theoretical and practical analysis of quantum computing as framed by foundational and contemporary literature. Drawing strictly from the selected scholarly references, this work synthesizes insights from quantum theory, computational models, fault tolerance, measurement based computation, and quantum enabled cloud systems to develop a unified perspective of how quantum computation can transition from experimental laboratories into scalable, reliable, and socially integrated computational ecosystems.

The abstract foundation of quantum computing is rooted in the physical principles of superposition, entanglement, and measurement, which fundamentally distinguish it from classical computation. Stolze and Suter emphasize that quantum computation is not merely an extension of classical digital logic but an entirely new way of encoding, manipulating, and extracting information from physical systems. This work expands on that view by systematically connecting physical quantum theory to algorithmic and architectural abstractions that define modern quantum information processing.

Beyond the physics, quantum computing must also be understood as a computational system subject to errors, decoherence, and operational constraints. Paler and Devitt highlight the centrality of fault tolerance in making quantum computing viable, arguing that without systematic error correction, quantum advantage remains purely theoretical. This article develops an extended conceptual framework showing how fault tolerant design principles interact with hardware, software, and algorithmic layers of quantum systems.

At the same time, the symbolic and logical representation of quantum processes, discussed by Wu, introduces a critical philosophical and practical question: whether quantum computing should be understood primarily as a physical phenomenon or as a new symbolic system for manipulating information. By analyzing this debate in detail, this paper shows that quantum computing is best viewed as a hybrid discipline in which physical reality and symbolic abstraction are inseparably linked.

The broader technological and social context of quantum computing is explored through the lens of quantum cloud computing, as discussed by Grodzinsky, Wolf, and Miller, as well as Singh and Sachdev. Their work reveals how quantum computing may be delivered as a service, raising new issues of trust, accessibility, and governance. This article integrates these perspectives into a comprehensive view of how quantum technologies may reshape the future of global computing infrastructure.

Keywords: Quantum computing, fault tolerance, qubits, measurement based computing, quantum cloud, computational models.

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Cite This Article: Sofia Moreira. 2026. Toward a Unified Theoretical and Practical Framework for Quantum Computing and Quantum Enabled Cloud Architectures. American Journal of Computer Science and Quantum Technologies 2, 01, 8-10. <https://doi.org/10.64917/ajcsqt/V02I01-002>

1. Introduction

The history of computing is deeply rooted in the attempt to formalize and mechanize reasoning. Classical computing emerged from mathematical logic, electrical engineering, and information theory, forming a technological system capable of representing symbols and executing algorithms at unprecedented speeds. However, as Barila explains, classical computing is ultimately constrained by the physical laws governing classical systems, particularly in its reliance on binary states and deterministic logic gates. Quantum computing arises from the recognition that physical reality itself is governed by quantum mechanics, and therefore computation need not be limited to classical representations of information (Barila, 2014).

Stolze and Suter describe quantum computing as a radical departure from classical paradigms because it encodes information in quantum states that can exist in superpositions and can be entangled with one another in ways that have no classical analogue. This means that quantum systems do not simply process bits, but qubits, which represent a richer and more complex form of information. The importance of this shift cannot be overstated. Classical computing models assume that information is always in a definite state, whereas quantum computing allows information to exist in multiple potential states simultaneously until measured (Stolze and Suter, 2019).

The promise of quantum computing is often described in terms of exponential speedups for certain problems, such as factorization and search. However, as Bertels cautions, the question is not merely whether quantum computers can solve certain problems faster, but how far we are from building machines that can do so reliably and at scale. The gap between theoretical possibility and technological reality remains large, and this gap is shaped by physical, engineering, and computational challenges (Bertels, 2015).

A major literature gap exists in the integration of these diverse perspectives. Some works focus primarily on the physics, others on the algorithms, others on system architecture, and still others on social and infrastructural implications such as cloud computing. Yet quantum computing, as a transformative technology, requires a holistic understanding that unifies these layers into a

coherent conceptual framework. The aim of this article is to address that gap by synthesizing the provided references into a comprehensive, publication ready theoretical model of quantum computing and its future deployment.

2. Methodology

The methodological approach of this research is conceptual and integrative. Rather than conducting experimental or numerical analysis, this work employs a systematic interpretive methodology grounded in the provided literature. The references were analyzed in terms of their theoretical assumptions, technological frameworks, and conceptual models of quantum computing. Stolze and Suter provide the physical and experimental foundations, Bertels and Kaizer Vizzotto offer insights into the technological state of the art, Paler and Devitt contribute the theory of fault tolerance, Wu contributes a symbolic and philosophical perspective, and Grodzinsky, Singh, and others contribute the cloud computing and social infrastructure dimension.

The methodology involves cross comparing these sources to identify convergences, contradictions, and gaps. For example, fault tolerant computing is examined not only as a technical requirement but also as a bridge between physical fragility and computational reliability. Similarly, measurement based quantum computing is interpreted not only as an alternative model of computation but as a redefinition of how information is extracted from quantum systems (Morimae, 2014).

This integrative methodology allows the development of a layered theoretical model in which quantum physics, computational logic, and digital infrastructure are treated as interdependent components of a single evolving system.

3. Results

The analysis reveals that quantum computing can be understood as a three layered system. The first layer is the physical layer, consisting of qubits, quantum gates, and measurement processes. Stolze and Suter emphasize that qubits are not merely abstract symbols but physical systems that must be carefully controlled and isolated from environmental noise. This means that the reliability of quantum computation is fundamentally tied to the quality of physical hardware.

The second layer is the computational layer, which includes algorithms, error correction, and fault tolerance. Paler and Devitt show that quantum error correction is not an optional enhancement but a necessary condition for scalable quantum computing. Without fault tolerance, errors accumulate faster than they can be corrected, rendering long computations impossible.

The third layer is the infrastructural and social layer, which includes cloud computing, user access, and trust. Grodzinsky and colleagues argue that quantum computing will likely be accessed remotely through cloud platforms, making issues of trust and transparency central to its adoption (Grodzinsky et al., 2011). Singh and Sachdev further show that quantum cloud models may enable broader access to quantum resources but also introduce new challenges in security and governance (Singh and Sachdev, 2014).

4. Discussion

The integration of these layers reveals a fundamental insight: quantum computing is not merely a faster form of classical computing but a new socio technical system. Wu argues that quantum computing challenges the traditional notion of computation as symbolic manipulation because quantum processes cannot be fully represented by classical symbols alone (Wu, 2015). This creates a tension between physical realism and computational abstraction that must be resolved through new theoretical frameworks.

One limitation of current research is that much of quantum computing theory assumes idealized conditions that are difficult to achieve in practice. Decoherence, noise, and imperfect control remain significant barriers. Kaizer Vizzotto highlights that while experimental progress is impressive, true large scale quantum computing remains a long term goal (Kaizer Vizzotto, 2013).

Future research must therefore focus on bridging the gap between theory and practice, particularly in the development of robust fault tolerant architectures and scalable cloud based delivery models.

5. Conclusion

This article has demonstrated that quantum computing must be understood as an integrated system of physical processes, computational logic, and digital infrastructure. By synthesizing the provided references, it has shown that the future of quantum computing depends not only on advances in physics but also on developments in fault tolerance, symbolic representation, and cloud based access. The

transformation of quantum computing from a laboratory curiosity into a global computing platform will require a unified theoretical and practical framework, such as the one outlined in this work.

References

1. Barila, A. From classical computing to quantum computing. Development and Application Systems International Conference, 2014.
2. Bertels, K. Quantum computing how far away is it. High Performance Computing and Simulation International Conference, 2015.
3. Grodzinsky, F S, Wolf, M J, and Miller, K W. Quantum computing and cloud computing humans trusting humans via machines. IEEE International Symposium on Technology and Society, 2011.
4. Hahanov, V I, Hyduke, S M, Gharibi, W, Litvinova, E I, Chumachenko, S V, and Hahanova, I V. Quantum models and method for analysis and testing computing systems. Information Technology New Generations International Conference, 2014.
5. Kaizer Vizzotto, J. Quantum computing state of art and challenges. Workshop School on Theoretical Computer Science, 2013.
6. Morimae, T. Basics and applications of measurement based quantum computing. International Symposium on Information Theory and its Applications, 2014.
7. Paler, A and Devitt, S J. An introduction into fault tolerant quantum computing. Design Automation Conference, 2015.
8. Singh, H and Sachdev, A. The quantum way of cloud computing. International Conference on Optimization Reliability and Information Technology, 2014.
9. Stolze, J and Suter, D. Quantum Computing A Short Course from Theory to Experiment. Wiley Publications.
10. Wu, C H. Qubits or symbolic substitutions for general purpose quantum computing. Information Technology New Generations International Conference, 2015.