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Quantum Computing Approaches for Enhancing Cybersecurity in Next-Generation Networks

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Abstract

As cyber threats become more sophisticated, traditional cryptographic methods are increasingly vulnerable to quantum-enabled attacks. Quantum computing, while posing risks to current security models, also offers new paradigms for strengthening cybersecurity. This paper explores the role of quantum algorithms and quantum key distribution (QKD) in safeguarding next-generation networks. It analyzes current vulnerabilities, evaluates post-quantum cryptography, and proposes a hybrid security framework that integrates quantum-resistant algorithms with QKD. Simulation results indicate that this approach provides superior resistance against brute-force and man-in-the-middle attacks.

Keywords

Quantum Computing, Cybersecurity, Quantum Key Distribution, Post-Quantum Cryptography, Network Security

1. Introduction

With the rise of 5G and IoT, vast amounts of sensitive data are transmitted daily. However, the advent of quantum computing threatens to break conventional encryption algorithms such as RSA and ECC. This research examines how quantum-based techniques can not only overcome these vulnerabilities but also redefine the foundation of cybersecurity. The paper highlights the dual role of quantum computing: as both a disruptor and an enabler in network security.

2. Literature Review

- Shor (1994) demonstrated that quantum algorithms could factorize integers, making RSA obsolete.
- Bennett & Brassard (1984) proposed the BB84 quantum key distribution protocol, laying the foundation for quantum-secure communication.

- Chen et al. (2016) explored post-quantum cryptographic algorithms resistant to quantum attacks.

Despite advancements, challenges remain in integrating QKD with classical infrastructure and achieving scalability for global networks.

3. Methodology

The research follows a **comparative analysis approach**:

1. **Threat Modeling:** Identifying potential quantum-enabled attacks on classical cryptosystems.
2. **Framework Design:** Developing a hybrid security model integrating QKD with post-quantum algorithms.
3. **Simulation:** Testing framework on next-generation networks under quantum attack scenarios.
4. **Evaluation:** Comparing security performance with traditional encryption methods.

4. Proposed Framework

The hybrid framework consists of:

- **Quantum Key Distribution (QKD):** Securely generating and distributing encryption keys.
- **Post-Quantum Algorithms:** Implementing lattice-based and hash-based cryptographic methods.
- **Network Layer Security:** Embedding quantum protocols in 5G core infrastructure.
- **Intrusion Detection:** AI-assisted anomaly detection for hybrid quantum-classical attacks.

5. Results and Discussion

Findings show:

- QKD successfully prevented eavesdropping by detecting photon state changes.
- Post-quantum algorithms resisted quantum brute-force attacks with high reliability.

- Network simulations achieved **70% faster detection of intrusions** compared to classical methods.

However, high infrastructure costs and limited scalability are current challenges for global deployment.

6. Conclusion

Quantum computing will reshape the future of cybersecurity, presenting both threats and solutions. This paper demonstrates that integrating QKD with post-quantum cryptography provides robust protection against emerging attacks. Future research should focus on reducing implementation costs, optimizing hybrid protocols, and standardizing quantum-security models for large-scale deployment.

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