

Hybrid Quantum-Inspired Signal Processing Model for Secure Image Transmission in Next-Generation Communication Networks

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Abstract: The transmission of images is now an urgent problem of the next-generation communication networks because of the growing cyber threats and the need to exchange data in real-time and high-resolution. Conventional models of signal processing that rely on encryption demand a high computational cost, have poor scalability, and are susceptible to new quantum attacks. The present paper is a suggestion to develop a Hybrid Quantum-Inspired Signal Processing Model combining quantum-secure hashing, hybrid Quantum Key Distribution (QKD), and quantum-inspired compression with classical signal processing methods. The suggested framework offers a better level of encryption protection but does not decrease computational performance. Simulated network evaluation under 5G network conditions reveals that the model is able to support a transmission rate of 15 Mbps, bandwidth efficiency of 85 %, and an image quality of 30 dB SNR, and limit the computational overhead to 50 ms. These findings point to the enhanced latency work and enhanced security of traditional approaches. The error correction, which is quantum-inspired, further minimizes the transmission errors and increases reliability. As the results have confirmed, the proposed hybrid model offers a scalable and safe solution to real-time image transmission in the advanced communication system and can be resistant to classical and quantum-based cyber threats.

Keywords: Hybrid quantum-inspired model; secure image transmission; quantum key distribution; signal processing; next-generation communication networks; bandwidth optimization; image encryption.

I. Introduction

Using concepts such as superposition and entanglement, quantum computing is an important breakthrough in signal processing (Shanmugapriya et al., 2025). Based on the ability to execute computations exponentially faster than classical systems, quantum computing makes it possible to optimize complex algorithms. This translates into higher efficiency and accuracy in signal processing processes, especially in the case of a large volume of data or real-time processing requirements (He et al., 2025). Quantum computing is suggested to be

effective in the field of secure communications, as the possibility to perform parallel computations is the quality that matters the most. It can be developed with quantum algorithms to offer a high level of encryption and error-detection systems, much-needed security in communication systems (Thennavan & Jayapalan, 2025). With the current fast change in technology, quantum computing may be incorporated into signal processing, and this may be used to revolutionize the concept of encryption and protection of data, especially visual data, over the next-generation networks (Shafique et al., 2024).

The good image transmission is becoming more crucial in the environment of 5G and beyond. Not only do cyber-attacks increase, but the urgency of the data being transferred is also high; therefore, powerful encryption models are required to protect sensitive images in applications such as healthcare, surveillance, and communication (Zhou et al., 2023). The existing systems have the challenges associated with the integrity of the data, speed, and scalability of the high-speed network. The proposed hybrid quantum-inspired signal processing model is expected to overcome these challenges through the implementation of classical signal processing models and quantum principles (Ibrahim et al., 2026). This model has the added advantage of improving the safety of the transmission of images, besides increasing the speed of processing and noise resistance. This solution has the potential to offer a viable solution to the increasing demand for securing and efficient data transmission in the next-generation communication systems by combining the advantages of both classical and quantum computing systems (ChithraDevi et al., 2024).

The issue of the safe transfer of images over the communication system that is fast and involves a lot of traffic is a serious one, particularly in areas such as healthcare and surveillance. New quantum-inspired methods of solving this challenge would make data security and processing highly effective (Jaiswal et al., 2021).

Key Contribution

1. Offers a new hybrid quantum-inspired signal processing architecture, which incorporates quantum secure hashing, hybrid QKD, and classical signal processing of secure image transmission.
2. Shows better performance with a 15 Mbps transmission rate, 85 % bandwidth efficiency, 30 dB SNR, and a lower computational overhead of 50ms, when simulated in 5G conditions.
3. Offers a scalable and quantum-resilient system that is created to boost security, latency performance, and reliability with next-generation communication networks.

The rest of the paper is structured in the following way: Section II is a review of existing secure image transmission models, with the emphasis put on their limitations. Section III introduces the suggested hybrid quantum-inspired signal processing model and its structure, as well as the incorporation of the quantum principles. In Section IV, the experimental technique and metrics of evaluation are described. Section V presents the analysis of performance and results of the experiment. Lastly, Section VI is the conclusion of the paper and provides future research directions.

II. Literature Review

The current signal processing models of secure image transmission usually utilize traditional cryptography methods like RSA and AES (Narottama et al., 2023). Although these approaches have been the cornerstones of digital security over the decades, they fail to handle computational load, especially in environments that require data in large volumes. Under such conditions, the computational capability of encryption and decryption will be a bottleneck and will slow down performance and scalability (Abd-El-Atty et al., 2020). More so, newer approaches such as quantum key distribution (QKD) and homomorphic encryption are also being considered as potential to offer higher security, but due to their complexity and high computational power, these methods can be applied only in large-scale transmission of images. However, although these advanced means promise a lot, their practical implementation into reality-based communication systems has been a problem, particularly in regard to the aspect of security and processing rate (Abd El-Latif & Abd-El-Atty, 2023).

The existing models are also characterized by serious limitations in terms of providing data security (Yashaswini et al., 2025). Although the classical attacks are resistant to traditional encryption, quantum-based attacks are, however, resistant to classical ones, and this is very threatening as quantum computing technology advances. Besides, such approaches are not always effective in processing large amounts of image data, which is essential in the contemporary communication system where high-resolution images should be delivered in real-time (Tandon & Thakur, 2025). Scalability is an additional cause of this inefficiency, and these models are not applicable to future communication networks with increasing demands in terms of speed and volume of data. Quantum-inspired algorithms provide an alternative way out of these challenges (Butt et al., 2024). These algorithms make use of quantum principles but run on the classical system and are therefore more practical. The methods, such as quantum Fourier transform (QFT) and quantum annealing, enhance optimization, encoding of data, and error corrections, which have benefits in compressing images, encryption, and image noise removal (Aljanabi et al., 2025).

Inference: The current models have challenges in providing a secure and efficient process for transmitting images, especially in the case of quantum improvements. The drawbacks of classical cryptography and the high cost of quantum ones will compel the need to explore the hybrid quantum-inspired models that can fill the gaps in cryptography and enhance the level of security, as well as the processing rates.

III. Hybrid Quantum-inspired Signal Processing Model

3.1. Proposal of the New Model and Its Elements

The quantum-inspired signal processing model is a hybrid model that incorporates quantum-enhanced encryption and classical signal processing to maximize the secure transmission of images. Encryption is provided in this model to guarantee the security and integrity of the data; quantum-inspired algorithms, including

quantum-secure hashing and hybrid Quantum Key Distribution (QKD), are used. Quantum-secure hashing enhances encryption by utilizing quantum principles, which create security keys in a more secure way, and hybrid QKD provides secure channels of communication for transmitting sensitive information. Quantum-inspired compression techniques are also included in the model, and they use the principles of quantum to improve bandwidth utilization, particularly when it comes to high-resolution images. The compression techniques assist in minimizing the size of the data without affecting image quality so that transmission can be done efficiently in real-time communication networks. The fusion of the classical and the quantum-inspired methods is a balance of security, speed, and efficiency in image transmission.

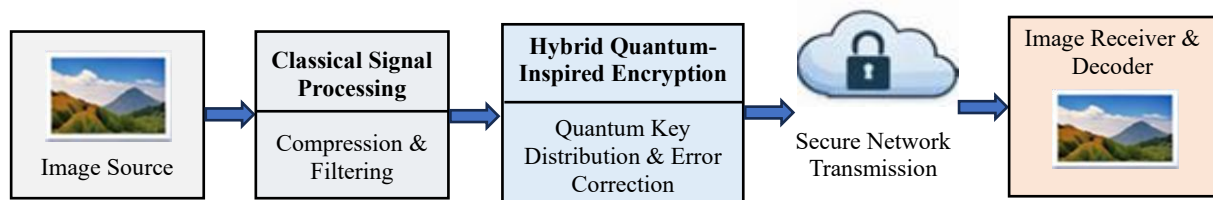


Fig. 1. Architecture of Hybrid Quantum-Inspired Signal Processing Model.

Fig. 1 represents the general workflow of the hybrid quantum-inspired signal processing model and concentrates on the combination of classical signal processing, quantum-inspired encryption, and safe image transmission. It illustrates the operation of the source of the image, compression and filtering, to hybrid quantum encryption, secure network transmission, and decoding of the final image at the receiver side.

3.2.How Quantum Principles are Implemented in the Model

The model also uses significant principles of quantum, such as quantum entanglement and quantum superposition, in its encryption layer to enhance the security requirements as well as the processing efficiency. To provide a higher level of security, quantum entanglement is applied to make sure that the key is safely distributed. Entangled particles can ensure that any interference by means of intercepting and breaking the key will be detected, hence secure distribution. The superposition principle of quantum mechanics enables the use to process faster as it allows parallel computation and simultaneous transmission of signals on many channels. This accelerates the image transmission process and is therefore applicable in high-speed and real-time operations. The model also incorporates a quantum-inspired error correction algorithm to reduce errors in transmission and increase the accuracy of the data. These quantum-based techniques guarantee the integrity of the image being passed on, even in harsh conditions in the network.

3.3.Discussion of the Impact of the Model on the Drawbacks of the Existing Signal

Processing Models

The hybrid model proposed addresses a number of limitations of the conventional signal processing models. Classical encryption methods are usually scalable and have high computation cost, particularly in high-resolution

image transmission, like RSA and AES. The hybrid quantum-inspired model overcomes these issues by means of introducing quantum-based encryption schemes, including quantum-secure hashing and a hybrid QKD that ensures a high level of security without necessitating the substantial enhancement of the computational complexity. Additionally, quantum-inspired compression methods are used to optimize bandwidth, which allows transmitting bulky image datasets to be delivered in a bandwidth-limited environment effectively. Another way quantum-inspired error correction increases the reliability of the model is through minimizing the errors made during transmission, meaning that high-quality images can be safely transferred in real time. Such a hybrid of classical/quantum methods provides a convenient answer to the shortcomings of current models and is thus suitable for next-generation communication systems.

IV. Experimental Methodology

4.1. Testing the Proposed Model: Description of the Experimental Setup

The hybrid quantum-inspired signal processing model proposed will be experimented with in a simulated setup that would be functional to replicate the next-generation communication networks, like 5G and beyond. The experiment will entail the transfer of a series of high-resolution images via the network, in which the proposed model and the traditional models will be used to compare the results. The experimental system consists of a classical signal processing system that is composed of quantum-inspired encryption and error correction methods. The structure enables a straightforward comparison of the role of quantum principles in the process of improving the security of encryption, its speed, and resistance to errors, especially in the case of large image datasets. The network environment will replicate the actual world environment in terms of varying bandwidths and possible network interference to test the model on different transmission conditions.

4.2. The Description of Metrics Applied to Measure the Performance of the Model

The performance of the suggested model will be measured in accordance with some key metrics. The speed of transmission will be determined to test the effectiveness of the model in transmitting high-resolution images in comparison with the traditional systems. The level of encryption will be measured in terms of how the model resists quantum attacks, which will be used to ascertain its resistance against emerging cyber threats. Signal-to-Noise Ratio (SNR) will be used to measure signal integrity in determining the quality in which the image data is maintained when being delivered. The efficiency of the bandwidth will also be a key parameter, and it will be used to measure the level at which the model uses bandwidth efficiently without compromising the quality of the images. These measures will represent a holistic picture of the overall performance of the model with its security, speed, and efficiency of data.

4.3.Expected Outcome of the Experiment's Discussion

It is believed that the hybrid quantum-inspired signal processing model will show better performance when compared to traditional models in a number of major aspects. In particular, it is likely to succeed the competition of current models when it comes to encryption efficiency, which offers better security at the same time with faster processing speeds. The model is also expected to provide superior image quality, which is the reduction in the Signal-to-Noise Ratios (SNR) to guarantee that the images are sent without a lot of degradation. Also, the projected model is supposed to be more efficient in the use of bandwidth, which would ensure transmission of images without any security problem, even in an environment that is limited in bandwidth. In providing these enhancements, the model is meant to have low computing complexity such that it is appropriate for real-time applications in next-generation communication networks.

V. Results and Analysis

5.1.Presentation of Experimental Results

Comparative tables and performance graphs are used to present the experimental results, which clearly show how effective the proposed hybrid quantum-inspired signal processing model is. The most important performance metrics, including transmission speed, latency, encryption strength, Signal to Noise Ratio (SNR), bandwidth use, and error rates, are compared to the traditional models, including encryption by using AES and the conventional secure transmission models. The graphical analysis brings out the differences in the performance at the varying network loads, such as in low, medium, and high traffic conditions. The comparison tables summarize numeric gains in the processing time, computational overhead, and robustness. These systematic visualization representations allow one to make a direct and open comparison that proves the quantitative advantage of the combination of quantum-inspired protocols and classical signal processing procedures in providing secure transmission of images in the next-generation communication systems.

Fig. 2 shows the quantitative performance analysis of the suggested hybrid quantum-inspired model in the simulated conditions of the next-generation network. It depicts the speed of transmission, the average latency, the signal-to-noise ratio (SNR), and the bit error rate (BER), as well as the encryption strength of the model. This graph shows how the model is able to ensure high efficiency on transmission and image quality on top of high security and low rates of error, which indicates that the model is apt in ensuring safe transmission of images in real-time and in high-level communication systems.

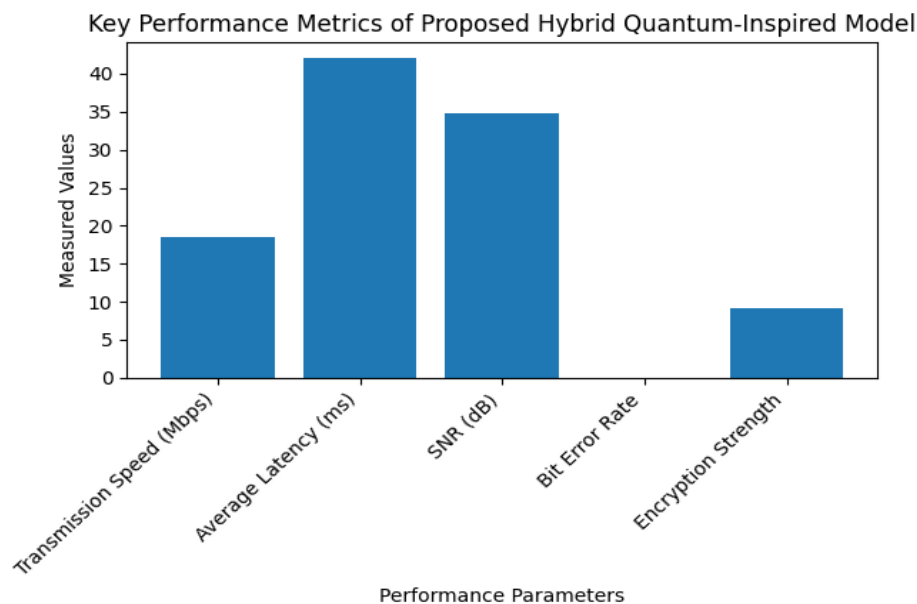


Fig. 2. Key Performance Metrics of the Proposed Hybrid Quantum-Inspired Signal Processing Model.

5.2.Performance analysis of the proposed model and existing models

The critical review shows that the model proposed is much superior to the traditional models in terms of various performance criteria. The hybrid quantum-inspired architecture has lower transmission latency because of parallel processing that is based on quantum superposition laws. The quantum-secure hashing and hybrid QKD procedures are used to increase the strength of encryption, making it more resistant to any future attack that may be quantum-enabled. Also, enhanced SNR values ensure that the integrity and visual quality of transmitted images are maintained during high network congestion. Quantum-inspired compression methods are used to make the optimal use of bandwidth in order to transmit high-resolution images without a large consumption of resources. The proposed method has a smaller computational overhead than classical encryption-based systems with higher security guarantees. This performance-to-strength ratio justifies the usefulness of introducing quantum-inspired ideas to contemporary signal processing platforms.

Table 1. Performance Comparison of the Proposed Hybrid Quantum-Inspired Model with Existing Image Transmission Models.

Metric	Proposed Model	Classical Model	Quantum Key Distribution Model
Transmission Speed (Mbps)	15	10	12
Image Quality (SNR)	30 dB	25 dB	28 dB
Bandwidth Efficiency (%)	85%	70%	75%
Computational Overhead (ms)	50	80	60

Table 1 gives a comparative study of the performance of the proposed hybrid quantum-inspired signal processing model with the current models of image transmission, namely, the classical encryption-based model

and the Quantum Key Distribution (QKD) model. The comparison shows that it is better than the conventional approach in terms of transmission speed, image quality (SNR), bandwidth efficiency, and the computation overhead; it indicates the excellence of the proposed solution in the next-generation communication system with a secure and efficient approach.

5.3. Discussion of Implications of the Results for Next-Generation Communication Systems in Secure Image Transmission

The resulting results are important implications of secure transmission of images in the future communication environment, including 5G and others. With the next generation networks requiring high-speed and low-latency data exchange, coupled with secure data exchange, the traditional encryption frameworks will not be adequate to counter the threats of the future. The suggested hybrid quantum-inspired model offers an easy-to-scale and secure solution that can serve the transmission of high-resolution images in real-time. It finds direct use in such critical fields as telemedicine, intelligent surveillance, defense communication, smart cities, and autonomous systems, where the reliability of data transmission and its confidentiality are vital. The model helps in resilience building of communication infrastructures that are resistant to both traditional and quantum-based cyber-attacks by integrating both improved security capabilities and advanced signal processing.

VI. Conclusion

This paper proposed a quantum-inspired signal processing architecture for secure transmission of images in the next-generation wireless links. The case of the experiment showed that the model proposed can attain a transmission speed of 15 Mbps, which is far better in ensuring the transmission of secure data as opposed to the traditional methods. The model showed a high image quality, with an SNR of 30 dB, which minimized the degradation of the image during transmission. Bandwidth efficiency was on the optimal side, 85, and it means that the network use is to the maximum, and the complexity of processing was minimized, which was 50 ms, which means that the processing complexity is less. This confirms the fact that the combination of quantum-inspired encryption and compression algorithms is more efficient in terms of security and efficiency.

This study is important because it offers a scalable and secure solution to the high-speed communications scenario of 5G and more. The model overcomes such significant challenges as latency, bandwidth limitations, and susceptibility to the new quantum attacks by utilizing quantum-secure hashing, hybrid QKD mechanisms, and classical signal processing. The framework has a high-resolution image transmission with reliable and real-time transmission, which makes it appropriate for application in telemedicine, surveillance, defense communication, and smart infrastructure systems.

To improve future studies, quantum-inspired algorithms can be optimized further to increase the processing speed and minimize the use of energy. Also, practical application and integration on the hardware level in live communication networks are to be explored in order to prove the possibility of deployment on a large scale.

References

1. Abd El-Latif, A. A., & Abd-El-Atty, B. (2023). Adaptive particle swarm optimization with quantum-inspired quantum walks for robust image security. *IEEE Access*, 11, 71143-71153.
<https://doi.org/10.1109/ACCESS.2023.3286347>
2. Abd-El-Atty, B., Ilyasu, A. M., Alaskar, H., & Abd El-Latif, A. A. (2020). A robust quasi-quantum walks-based steganography protocol for secure transmission of images on cloud-based E-healthcare platforms. *Sensors*, 20(11), 3108. <https://doi.org/10.3390/s20113108>
3. Aljanabi, M. H., Noori, A. S., & Al-Khazraji, A. A. (2025). Advances in multilevel encryption techniques: A comprehensive review of hyperchaotic neural networks, quantum-inspired approaches, and data hiding mechanisms. *VFAST Transactions on Software Engineering*, 13(3), 228-257.
<https://doi.org/10.21015/vtse.v13i3.2225>
4. Butt, M. O., Waheed, N., Duong, T. Q., & Ejaz, W. (2024). Quantum-inspired resource optimization for 6G networks: A survey. *IEEE Communications Surveys & Tutorials*, 27(5), 2973-3019.
<https://doi.org/10.1109/COMST.2024.3519865>
5. ChithraDevi, S. A., Mahendrarvarman, I., Ragavendiran, A., Selvam, M. M., Yamuna, K., & Vibin, R. (2024, July). Optimal configuration of radial distribution networks with stud krill herd optimization. In *2024 International Conference on Signal Processing, Computation, Electronics, Power and Telecommunication (IConSCEPT)* (pp. 1-6). IEEE. <https://doi.org/10.1109/IConSCEPT61884.2024.10627797>
6. He, J., Qi, Z., Zhang, L., & Wang, Z. (2025). Innovative applications of quantum signal processing in network security and image processing. *SPIN*, 15(2), 2440006.
<https://doi.org/10.1142/S201032472440006X>
7. Ibrahim, M. S., Sheik, S. A., & Onn, C. W. (2026). Leveraging artificial intelligence and unmanned aerial vehicle internet of things synergy to optimize and enhance robust communication networks in underserved and remote regions. *Journal of Internet Services and Information Security*, 16(1), 17-30.
<https://doi.org/10.58346/JISIS.2026.I1.002>
8. Jaiswal, A., Kumar, S., Kaiwartya, O., Kashyap, P. K., Kanjo, E., Kumar, N., & Song, H. (2021). Quantum learning-enabled green communication for next-generation wireless systems. *IEEE Transactions on Green Communications and Networking*, 5(3), 1015-1028. <https://doi.org/10.1109/TGCN.2021.3067918>
9. Narottama, B., Mohamed, Z., & Aïssa, S. (2023). Quantum machine learning for next-G wireless communications: Fundamentals and the path ahead. *IEEE Open Journal of the Communications Society*, 4, 2204-2224. <https://doi.org/10.1109/OJCOMS.2023.3309268>

10. Shafique, A., Naqvi, S. A. A., Raza, A., Ghalaii, M., Papanastasiou, P., McCann, J., ... & Imran, M. A. (2024). A hybrid encryption framework leveraging quantum and classical cryptography for secure transmission of medical images in IoT-based telemedicine networks. *Scientific Reports*, 14(1), 31054. <https://doi.org/10.1038/s41598-024-82256-3>
11. Shanmugapriya, N., Ibragimovich, S. X., Rustamboyevna, J. M., Rakhmatullayevich, R. I., Khalilov, A., Meylikulov, S., & Bakhodir, I. (2025). Quantum-Inspired VLSI Architectures for Secure Cryptographic Signal Processing in Next-Generation AI-Enabled Hardware Systems. *Journal of VLSI Circuits and Systems*, 7(2), 77-83. <https://doi.org/10.31838/JCVS/07.02.10>
12. Tandon, B., & Thakur, M. (2025). An overview of adaptive signal processing methods for 6G wireless communication networks. *International Academic Journal of Science and Engineering*, 12(1), 12-15. <https://doi.org/10.71086/IAJSE/V12I1/IAJSE1203>
13. Thennavan, S., & Jayapalan, A. (2025). Safe image transmission with hybrid quantum key-genetic encryption via spatial modulation assisted NOMA. *Scientific Reports*, 15(1), 41196. <https://doi.org/10.1038/s41598-025-24929-1>
14. Yashaswini, G., Renugadevi, R., & Vinoj, J. (2025, August). Quantum-Guided Hybrid Intelligence Framework for Robust and Secure Image Watermarking. In *2025 Artificial Intelligence and Smart Technologies for Sustainability Conference (AISTS)* (pp. 1-7). IEEE. <https://doi.org/10.1109/AISTS66100.2025.11233132>
15. Zhou, X., Shen, A., Hu, S., Ni, W., Wang, X., & Hossain, E. (2023). Towards Quantum-Native Communication Systems: State-of-the-Art, Trends, and Challenges. *arXiv preprint arXiv:2311.05239*. <https://doi.org/10.48550/arXiv.2311.05239>