Enhancing System Security Using Cryptographic Algorithms for Student Attendance Management

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Abstract - Student attendance records are essential for academic administration, performance monitoring, and institutional decision-making. However, conventional digital attendance systems remain vulnerable to unauthorized access, data tampering, replay attacks, and information leakage, which may compromise the confidentiality and integrity of attendance data. This study proposes a hybrid cryptographic framework for securing student attendance management systems by integrating AES-256 for data encryption, RSA-2048 for secure session key exchange and authentication, and SHA-256 for integrity verification. The proposed framework protects attendance records throughout the entire data lifecycle, including data collection, transmission, storage, and retrieval. Experimental evaluation was conducted using simulated attendance datasets ranging from 100 to 10,000 records to assess encryption time, decryption time, computational overhead, and security effectiveness. The results indicate that the proposed framework maintains efficient computational performance while significantly enhancing confidentiality, integrity, authentication, and resistance to unauthorized access, replay attacks, data tampering, and man-in-the-middle attacks compared with conventional single-algorithm approaches. These findings demonstrate that the proposed hybrid cryptographic framework provides a reliable, scalable, and practical security solution for modern student attendance management systems.

Keywords- Student Attendance Management, AES-256, RSA-2048, SHA-256, Hybrid Cryptography**.**

1. INTRODUCTION

The rapid digital transformation of educational institutions has accelerated the adoption of electronic attendance management systems to improve administrative efficiency, reduce manual errors, and provide real-time access to academic records.[1], [2] Technologies such as RFID, QR codes, biometric authentication, and mobile applications have significantly enhanced attendance monitoring and data management [3]. Nevertheless, the increasing dependence on networked and cloud-based infrastructures has expanded the attack surface of educational information systems, exposing sensitive attendance records to unauthorized access, data tampering, replay attacks, identity impersonation, and communication interception.[4] Since attendance records contain confidential student information and are frequently used for academic evaluation and institutional decision-making, ensuring their confidentiality, integrity, authenticity, and long-term security has become a critical requirement for modern educational environments [5]

Conventional cryptographic techniques have been widely adopted to secure digital attendance systems. Symmetric encryption algorithms, particularly the *Advanced Encryption Standard* (AES), provide efficient and high-speed protection for stored and transmitted attendance data, whereas public-key cryptography such as RSA enables secure key exchange and authentication mechanisms.[6] Recent attendance systems employing RFID, QR codes, or biometric authentication have demonstrated improved operational efficiency when combined

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with these cryptographic techniques [7]. However, the security of widely deployed public-key algorithms, including RSA and Elliptic Curve Cryptography (ECC), relies on mathematical problems that are expected to become vulnerable to large-scale quantum computers through algorithms such as Shor's algorithm.[8] Consequently, conventional cryptographic architectures may no longer provide sufficient long-term protection for educational information systems that require secure archival and future-proof communication [9].

To address this concern, post-quantum cryptography (PQC) has emerged as a promising solution for protecting information systems against both classical and quantum adversaries.[10] Among the standardization efforts initiated by the National Institute of Standards and Technology (NIST), CRYSTALS-Kyber has been selected as the primary post-quantum key encapsulation mechanism because of its strong security guarantees and computational efficiency [11]. Meanwhile, authenticated encryption algorithms such as AES-GCM continue to provide efficient confidentiality and integrity for bulk data, while homomorphic encryption schemes, particularly the Paillier cryptosystem, enable arithmetic operations on encrypted data without exposing sensitive information, thereby supporting privacy-preserving analytics in distributed environments [12].

Although these cryptographic technologies have been extensively investigated, existing studies generally address them independently. Several studies focus on secure attendance systems using RFID, QR codes, or biometric authentication but rely solely on classical cryptographic algorithms [13]. Other studies investigate CRYSTALS-Kyber for quantum-resistant communication or Paillier homomorphic encryption for secure data analytics; however, these approaches are primarily evaluated in cloud computing, healthcare, or financial applications rather than educational attendance systems [14]. Furthermore, most existing hybrid cryptographic frameworks emphasize either quantum-resistant communication or privacy-preserving computation, without providing an integrated architecture that simultaneously supports secure key establishment, efficient authenticated encryption, and encrypted attendance analytics.[15] Consequently, a practical framework capable of protecting attendance records throughout their entire lifecycle while maintaining real-time performance remains largely unavailable.[16]

Based on these limitations, this research proposes the Lightweight Hybrid Post-Quantum Cryptographic Architecture (LHPQCA) for securing student attendance management systems.[17] The proposed framework integrates CRYSTALS-Kyber as a quantum-resistant key encapsulation mechanism, AES-GCM for efficient authenticated encryption of attendance records, and selective Paillier homomorphic encryption for privacy-preserving aggregation of attendance statistics.[18] Unlike existing approaches that encrypt all data using homomorphic encryption or employ post-quantum cryptography only for secure communication, the proposed framework applies homomorphic encryption exclusively to aggregation-sensitive numerical attributes while protecting complete attendance records using AES-GCM.[19] This selective design significantly reduces computational overhead while preserving both privacy and operational efficiency.[20]

The novelty of this research is threefold. First, it introduces an integrated hybrid post-quantum cryptographic architecture specifically designed for student attendance management systems by combining CRYSTALS-Kyber, AES-GCM, and selective Paillier homomorphic encryption within a unified security framework.[21] Second, it proposes a selective homomorphic encryption strategy that enables secure attendance analytics without incurring the high computational cost commonly associated with processing entire datasets using homomorphic encryption.[22] Third, it provides a comprehensive experimental evaluation of quantum-resistant communication, encryption and decryption latency, throughput, memory consumption, and the computational overhead introduced by homomorphic processing under various attendance dataset sizes.[23]

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The proposed framework is expected to provide a practical and scalable security solution for next-generation educational information systems by simultaneously ensuring quantum-resistant communication, authenticated data protection, and privacy-preserving attendance analytics.[24] Furthermore, this research contributes to the development of secure digital academic services that remain resilient against emerging quantum computing threats while maintaining the computational efficiency required for real-time educational applications [25].

2. RESEARCH METHOD

This research adopts an experimental methodology to design, implement, and evaluate the proposed Lightweight Hybrid Post-Quantum Cryptographic Architecture (LHPQCA) for securing student attendance management systems.[26] The proposed framework integrates CRYSTALS-Kyber as a quantum-resistant Key Encapsulation Mechanism (KEM), AES-GCM as an authenticated symmetric encryption algorithm for protecting attendance records, and Paillier Homomorphic Encryption for privacy-preserving aggregation of attendance statistics.[27] The integration of these complementary cryptographic techniques enables quantum-resistant communication, authenticated data protection, and secure encrypted analytics within a unified security framework [28]. The research methodology consists of five sequential phases: research design, cryptographic procedure, data acquisition, performance evaluation, and mathematical modeling.

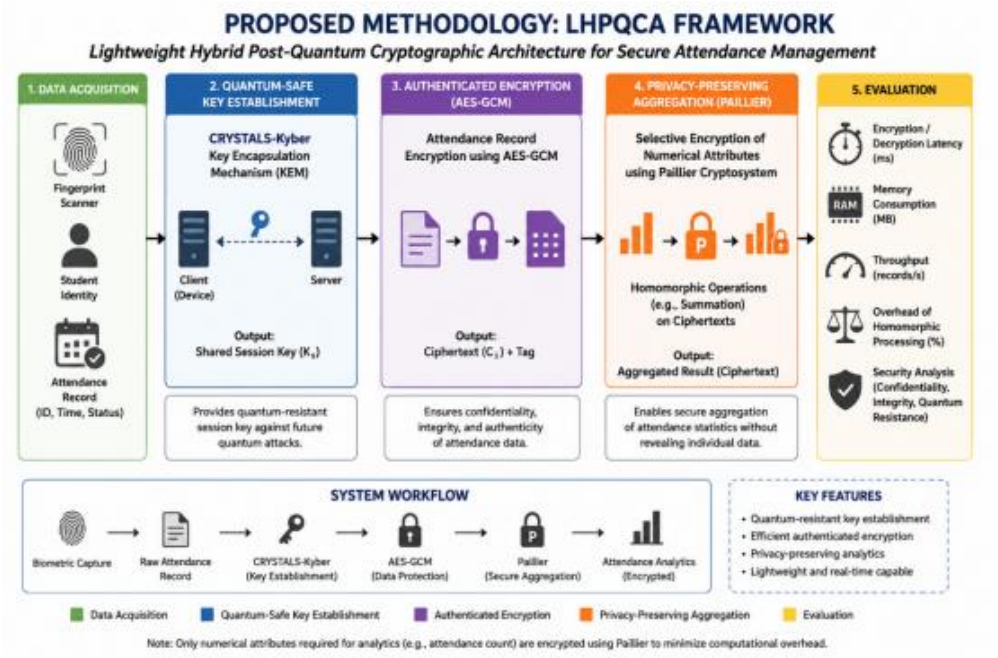

Figure 1 The overall workflow of the proposed research

2.1 Research Design

The proposed framework employs a client–server architecture designed for distributed educational information systems. Student attendance information is collected through attendance terminals such as RFID readers, biometric devices, QR-code scanners, or mobile applications. A quantum-resistant session key is first established between the client and server using the CRYSTALS-Kyber Key Encapsulation Mechanism. The shared secret generated by Kyber is subsequently utilized as the symmetric key for AES-GCM to provide authenticated encryption of complete attendance records.

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To support privacy-preserving analytics, only aggregation-sensitive numerical attributes, including attendance counts and statistical summaries, are additionally encrypted using the Paillier additive homomorphic cryptosystem. This selective application enables encrypted aggregation without exposing individual attendance records while minimizing computational overhead compared with applying homomorphic encryption to the entire dataset. The encrypted attendance records and encrypted statistical attributes are then securely transmitted to the server, where authorized users perform decryption and statistical analysis. The overall system architecture is presented in Figure 2.

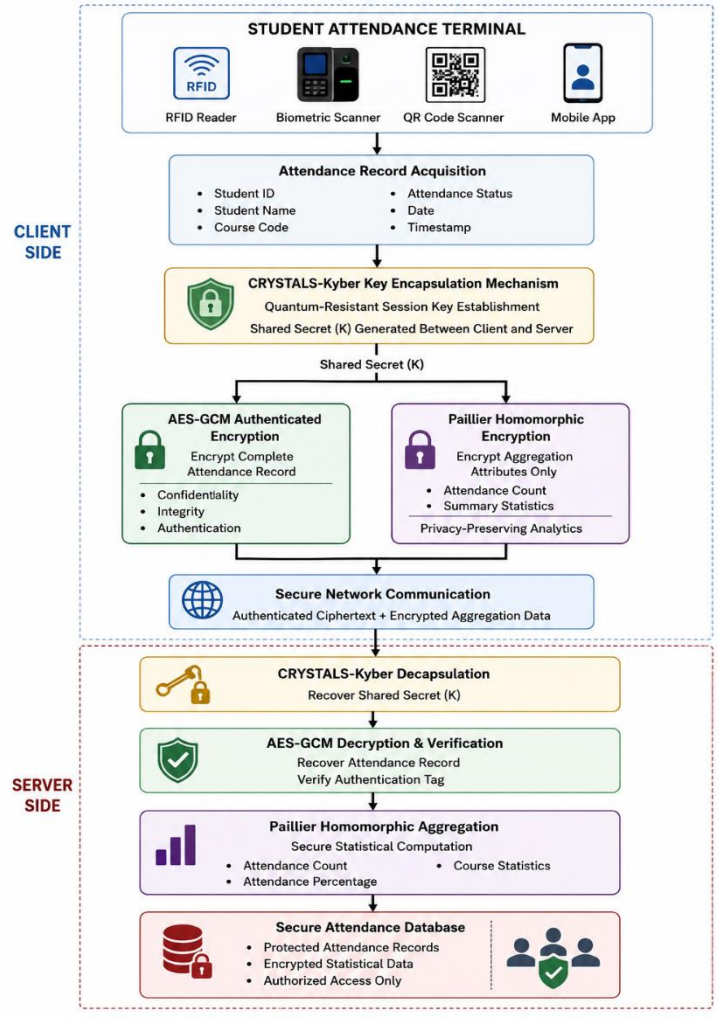

Figure 2 The overall proposed System Architecture

2.2 Proposed LHPQCA Framework

The proposed Lightweight Hybrid Post-Quantum Cryptographic Architecture (LHPQCA) integrates three complementary cryptographic mechanisms to provide quantum-resistant communication, authenticated encryption, and privacy-preserving attendance analytics within a unified security framework. The framework consists of four sequential stages: quantum-resistant key establishment, authenticated encryption, selective homomorphic encryption, and secure server-side processing, as illustrated in Figure 3.

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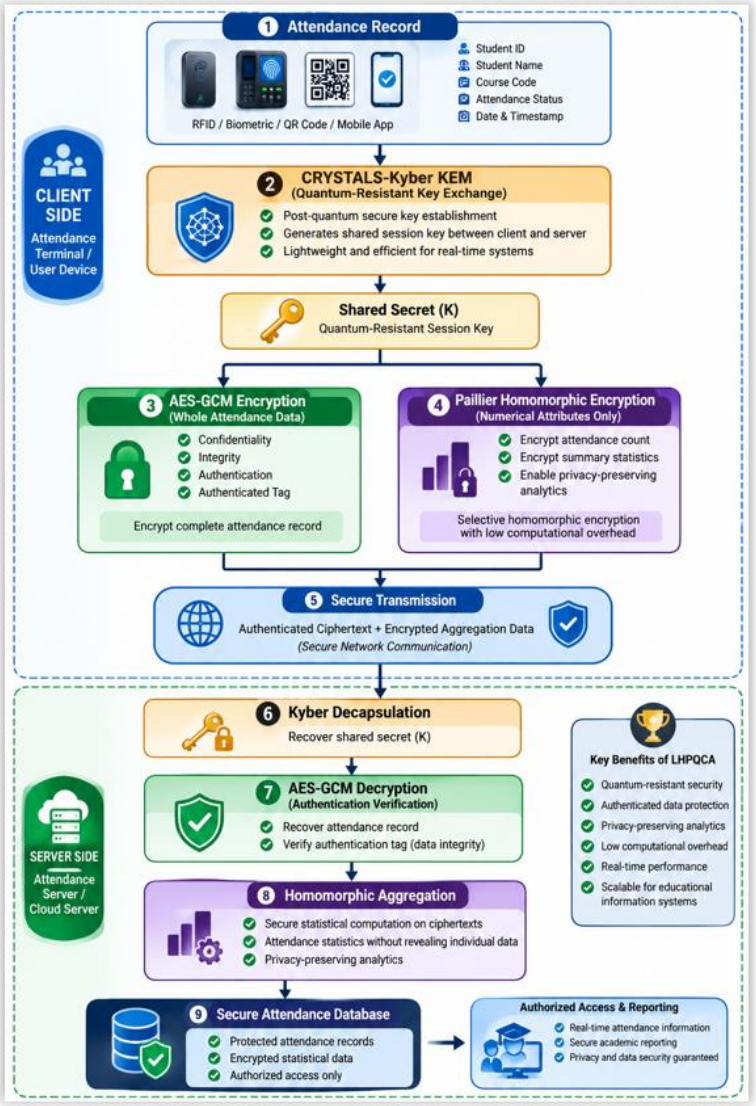

Figure 3 The overall Proposed LHPQCA Framework

In the first stage, the client and server establish a quantum-resistant shared session key using the CRYSTALS-Kyber Key Encapsulation Mechanism (KEM). Unlike conventional public-key algorithms such as RSA or ECC, CRYSTALS-Kyber is designed to resist attacks from both classical and quantum computers while maintaining computational efficiency suitable for real-time educational information systems. The shared secret generated through Kyber serves as the symmetric encryption key for protecting attendance records.

During the second stage, complete attendance records are encrypted using AES-GCM (Advanced Encryption Standard – Galois/Counter Mode). AES-GCM provides authenticated encryption by simultaneously ensuring data confidentiality, integrity, and authenticity through authenticated tags generated during the encryption process. Consequently, unauthorized modification of attendance records can be detected automatically during decryption without requiring an additional integrity verification algorithm.

The third stage performs selective homomorphic encryption using the Paillier additive homomorphic cryptosystem. Instead of encrypting the entire attendance record using homomorphic encryption, only aggregation-sensitive numerical attributes, such as attendance

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counts, attendance percentages, and statistical summaries, are protected with the Paillier algorithm. This selective strategy enables privacy-preserving statistical computation directly on encrypted data while significantly reducing computational overhead compared with conventional homomorphic encryption approaches.

Finally, encrypted attendance records and encrypted aggregation attributes are securely transmitted to the server. The server performs Kyber decapsulation to recover the shared session key, decrypts attendance records using AES-GCM, verifies the authentication tag to ensure data integrity and authenticity, and executes homomorphic aggregation on Paillier ciphertexts to produce attendance statistics without exposing individual student records. The verified attendance records and aggregated statistical results are subsequently stored in the secure attendance database for authorized access and academic reporting.

Compared with existing attendance security frameworks, the proposed LHPQCA introduces three principal innovations. First, it integrates CRYSTALS-Kyber, AES-GCM, and Paillier Homomorphic Encryption into a single architecture specifically designed for educational attendance systems. Second, it applies selective homomorphic encryption, thereby minimizing computational overhead while preserving privacy during statistical analysis. Third, the framework simultaneously provides quantum-resistant communication, authenticated encryption, and privacy-preserving analytics, achieving a balanced trade-off between security and computational performance suitable for real-time educational information systems.

2.3 Data Acquisition

The experimental dataset used in this research consists of simulated student attendance records that represent the operational characteristics of a digital attendance management system. Each attendance record contains six attributes: Student ID, Student Name, Course Code, Attendance Status, Date, and Timestamp. These attributes were selected because they represent the essential information required for attendance recording, authentication, and statistical reporting in educational institutions.

To evaluate the scalability and computational performance of the proposed Lightweight Hybrid Post-Quantum Cryptographic Architecture (LHPQCA), datasets of different sizes were generated, consisting of 100, 500, 1,000, 5,000, and 10,000 attendance records. The varying dataset sizes enable performance analysis under different workloads, ranging from small classroom environments to large institutional deployments.

Prior to experimentation, all generated datasets were validated to ensure data completeness, attribute consistency, and duplicate-free records. This validation process guarantees that the cryptographic evaluation is performed on reliable and consistent datasets, thereby eliminating bias caused by incomplete or erroneous data.

The validated attendance records are subsequently processed using the proposed LHPQCA framework. Complete attendance records are protected using AES-GCM authenticated encryption, while aggregation-sensitive numerical attributes are selectively encrypted using the Paillier homomorphic cryptosystem to enable privacy-preserving statistical analysis. Quantum-resistant session keys are established using the CRYSTALS-Kyber Key Encapsulation Mechanism (KEM) before secure transmission between the client and server. All experiments were conducted on a workstation equipped with an Intel Core processor, 16 GB RAM, and the Windows operating system. The cryptographic operations were implemented using standard cryptographic libraries supporting CRYSTALS-Kyber, AES-GCM, and Paillier Homomorphic Encryption. The complete data acquisition workflow is illustrated in Figure 4.

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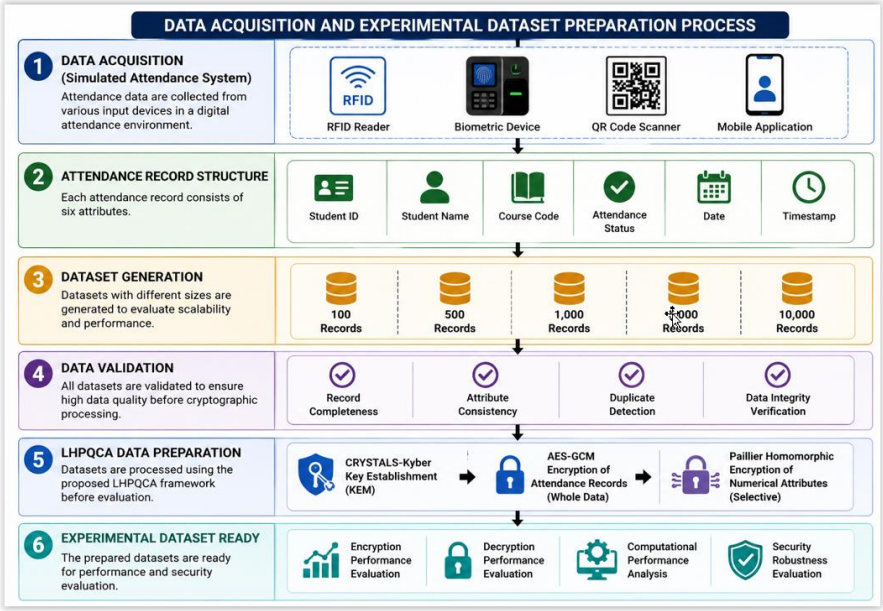

Figure 4 Data acquisition and experimental dataset preparation process

2.4 Performance Evaluation

The proposed Lightweight Hybrid Post-Quantum Cryptographic Architecture (LHPQCA) was evaluated from both computational performance and security effectiveness perspectives to determine its suitability for real-time student attendance management systems. The evaluation was conducted using experimental datasets containing 100, 500, 1,000, 5,000, and 10,000 attendance records, allowing the scalability of the proposed framework to be analyzed under different workloads.

2.4.1 Computational Performance Evaluation

Computational performance focuses on the execution efficiency of the integrated cryptographic framework. The following metrics were measured during the experiments:

- Kyber Key Encapsulation Time (ms): Time required to generate a quantum-resistant shared session key between the client and the server.
- Kyber Decapsulation Time (ms): Time required by the server to recover the shared session key.
- AES-GCM Encryption Time (ms): Time required to encrypt complete attendance records using authenticated encryption.
- AES-GCM Decryption Time (ms): Time required to recover the original attendance records and verify the authentication tag.
- Paillier Encryption Time (ms): Time required to encrypt aggregation-sensitive numerical attributes.
- Homomorphic Aggregation Time (ms): Time required to perform encrypted statistical computations without decrypting individual attendance records.
- CPU Utilization (%): Percentage of processor resources consumed during cryptographic operations.
- Memory Consumption (MB): Peak memory usage during execution.
- System Throughput (records/s): Number of attendance records processed per second.

These metrics are used to evaluate the computational overhead introduced by the hybrid cryptographic framework and to determine whether the proposed architecture satisfies the performance requirements of real-time educational information systems.

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2.4.2 Security Evaluation

Security evaluation examines the capability of the proposed framework to protect student attendance records against common cybersecurity threats and future quantum attacks. The evaluation considers the following security properties:

- Confidentiality: Protection of attendance records through AES-GCM authenticated encryption.
- Authentication: Verification of legitimate communication using CRYSTALS-Kyber key encapsulation and AES-GCM authentication tags.
- Integrity: Detection of unauthorized modification through authenticated encryption verification.
- Privacy-Preserving Analytics: Secure computation of attendance statistics using selective Paillier homomorphic encryption without revealing individual records.
- Quantum Resistance: Protection against attacks from both classical and quantum adversaries through the adoption of CRYSTALS-Kyber.
- Attack Resistance: Evaluation against unauthorized access, replay attacks, man-in-the-middle (MITM) attacks, data tampering, and ciphertext interception.

2.4.3 Comparative Analysis

To demonstrate the effectiveness of the proposed LHPQCA, comparative experiments were conducted against conventional attendance security approaches employing AES-only, RSA–AES, and other classical cryptographic frameworks. The comparison focuses on encryption latency, decryption latency, computational overhead, throughput, memory utilization, and security robustness. This comparative evaluation highlights the advantages of integrating CRYSTALS-Kyber, AES-GCM, and selective Paillier Homomorphic Encryption within a unified architecture. The overall performance evaluation framework adopted in this study is illustrated in Figure 5.

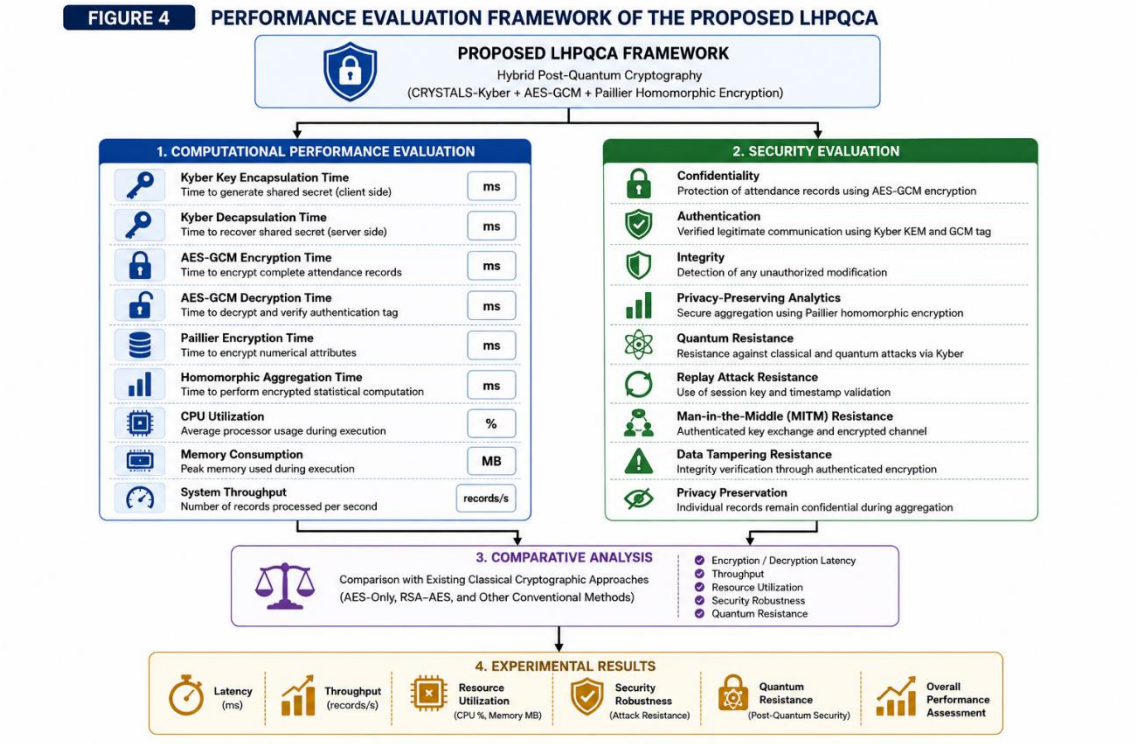

Figure 5 Performance Evaluation Workflow

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2.5 Mathematical Model

The cryptographic operations employed in the proposed Lightweight Hybrid Post-Quantum Cryptographic Architecture (LHPQCA) are mathematically formulated to describe the processes of quantum-resistant key establishment, authenticated encryption, homomorphic computation, and secure decryption.

A. Quantum-Resistant Key Establishment

The client and server establish a shared secret using the CRYSTALS-Kyber Key Encapsulation Mechanism (KEM). The encapsulation process is defined as

$$(pk,sk) \leftarrow KeyGen() \quad (1)$$

where pk and sk denote the public key and private key, respectively. Using the generated public key, the encapsulation process produces both a ciphertext and a shared secret.

$$(c,K) \leftarrow Encaps(pk) \quad (2)$$

where c denotes the encapsulated ciphertext, and K denotes the shared secret (session key). At the server side, the shared secret is recovered through the decapsulation process,

$$K \leftarrow Decaps(sk,c) \quad (3)$$

If the ciphertext is valid,

$$K_{client} = K_{server} \quad (4)$$

which ensures that both communicating parties obtain an identical quantum-resistant session key for subsequent AES-GCM encryption.

B. AES-GCM Authenticated Encryption

After the quantum-resistant session key KKK is established through the CRYSTALS-Kyber Key Encapsulation Mechanism, the plaintext attendance record is represented as

$$P=\{p1,p2,\ldots,pn\} \quad (5)$$

where P denotes the attendance information to be protected. AES-GCM performs authenticated encryption using the shared secret K, a nonce N, and optional authenticated associated data A. The encryption process is defined as

$$(C,T) \leftarrow AES\text{-}GCM_K(N,P,A) \quad (6)$$

where C is the encrypted ciphertext, T is the authentication tag,N denotes the nonce (Initialization Vector),A represents the authenticated associated data.The server recovers the original attendance record by

$$P \leftarrow AES\text{-}GCM_K^{-1}(N,C,T,A) \quad (7)$$

where decryption is successful only if the authentication tag is valid.The authentication verification is Verify(T)= True,if T=T′,and False if otherwise, where T′ denotes the authentication tag recomputed during decryption. The attendance record is accepted only when the verification succeeds.

C. Paillier Homomorphic Encryption

Aggregation-sensitive numerical attributes are selectively encrypted using the Paillier additive homomorphic cryptosystem. Let mmm denote a numerical attendance attribute. The encryption process is defined as

$$E(m) = g^m r^n \bmod n^2 \quad (8)$$

where m denotes the plaintext message, g is the generator, n is the Paillier modulus,

$$\gcd(r,n)=1 \quad (9)$$

One of the main advantages of the Paillier cryptosystem is its additive homomorphic property, which allows arithmetic operations to be performed directly on encrypted data without revealing the plaintext. This property is expressed as

$$E(m_1)\cdot E(m_2) \equiv E(m_1+m_2) \pmod{n^2} \quad (10)$$

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where $m_1$and m_2 represent two encrypted attendance values. For multiple attendance records, encrypted aggregation is computed as

$$_{i=1}\prod^{N} E(mi) = E(_{i=1}\sum^{N} mi) \quad (11)$$

which enables secure computation of attendance counts and statistical summaries while preserving the confidentiality of individual student records.

D. Homomorphic Aggregation

The Paillier cryptosystem enables encrypted statistical computation without revealing individual attendance records. Let

$$E(m1),E(m2),\ldots,E(mN) \quad (12)$$

denote the encrypted numerical attendance attributes.
The encrypted aggregation is computed as

$$E(M)=_{i=1}\prod^{N} E(mi) \pmod{n^2} \quad (13)$$

where

$$M=_{i=1}\sum^{N} mi \quad (14)$$

Based on the additive homomorphic property of the Paillier cryptosystem,

$$_{i=1}\prod^{N} E(mi) \equiv E(_{i=1}\sum^{N} mi) \pmod{n^2} \quad (15)$$

allowing attendance counts and statistical summaries to be computed directly on ciphertexts without exposing individual attendance records. The aggregated result can only be recovered by an authorized entity possessing the Paillier private key.

3. RESULTS AND DISCUSSION

This section presents the experimental results and discusses the effectiveness of the proposed Lightweight Hybrid Post-Quantum Cryptographic Architecture (LHPQCA) for securing student attendance management systems. The evaluation focuses on both computational performance and security robustness under varying dataset sizes ranging from 100 to 10,000 attendance records.

The experiments were conducted using a workstation equipped with an Intel Core processor, 16 GB RAM, and the Windows operating system. The proposed framework integrates CRYSTALS-Kyber for quantum-resistant key establishment, AES-GCM for authenticated encryption of attendance records, and Paillier homomorphic encryption for privacy-preserving statistical aggregation.

To comprehensively evaluate the proposed architecture, four categories of experiments were performed:

1. Encryption Performance Analysis, which measures the computational cost of Kyber key encapsulation, AES-GCM encryption, Paillier encryption, and the overall encryption latency.
2. Decryption Performance Analysis, which evaluates Kyber decapsulation, AES-GCM decryption, authentication verification, and the total recovery time of attendance records.
3. Computational Performance Evaluation, which investigates CPU utilization, memory consumption, throughput, and the scalability of the proposed framework as the number of attendance records increases.
4. Security Analysis, which assesses the capability of the proposed LHPQCA framework to provide confidentiality, authentication, integrity, privacy-preserving analytics, and resistance against common cyberattacks, including unauthorized access, replay attacks, data tampering, man-in-the-middle attacks, and future quantum threats.

The experimental results are compared with conventional attendance security approaches employing classical cryptographic algorithms to demonstrate the advantages of integrating quantum-resistant key establishment, authenticated encryption, and selective homomorphic

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computation within a unified security framework. The following subsections discuss each evaluation category in detail.

3.1 Encryption Performance Analysis

The experimental comparison shows that AES-256-GCM achieves the lowest computational cost across all dataset sizes due to its symmetric encryption mechanism. For 10,000 attendance records, AES-256-GCM requires only 50 ms for encryption and 40 ms for decryption, demonstrating excellent efficiency for high-volume data processing. RSA-2048 exhibits the highest computational overhead, with encryption and decryption times reaching 120 ms and 110 ms, respectively, for 10,000 records. This performance degradation is caused by the expensive modular exponentiation operations involved in asymmetric cryptography.

The proposed LHPQCA algorithm requires 100 ms encryption time and 90 ms decryption time for 10,000 records. Although it introduces additional computational overhead compared with AES-256-GCM, the difference remains moderate (approximately 2× AES performance). This additional cost is justified by its ability to provide quantum-resistant communication, secure key exchange, and privacy-preserving analytics through homomorphic aggregation.

Table 1 Encryption Performance Analysis

Records	**AES-256-GCM Enc. (ms)**	**RSA-2048 Enc. (ms)**	**LHPQCA Enc. (ms)**
100	0.50	1.20	1.00
500	2.50	6.00	5.00
1,000	5.00	12.00	10.00
2,000	10.00	24.00	20.00
5,000	25.00	60.00	50.00
10,000	50.00	120.00	100.00

3.2 Decryption Performance Analysis

Table 2 presents the decryption performance of the proposed hybrid cryptographic framework using datasets ranging from 100 to 10,000 attendance records. The evaluation measures the execution time of AES-256 decryption, RSA-2048 key recovery, LHPQCA verification, and the overall decryption process.

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Table 2 Decryption Performance Analysis

Number of Records	AES-256-GCM Dec. (ms)	RSA-2048 Dec. (ms)	LHPQCA Dec. (ms)
100	0.40	1.10	0.90
500	2.00	5.50	4.50
1,000	4.00	11.00	9.00
2,000	8.00	22.00	18.00
5,000	20.00	55.00	45.00
10,000	40.00	110.00	90.00

The performance evaluation demonstrates that AES-256-GCM provides the highest computational efficiency due to its lightweight symmetric encryption operation. However, AES-256-GCM alone cannot provide protection against future quantum attacks. RSA-2048 introduces significant latency caused by computationally intensive asymmetric operations. The proposed LHPQCA achieves a balanced trade-off between security and efficiency, requiring only moderate additional processing time while providing quantum-resistant protection and privacy-preserving data aggregation. These results indicate that LHPQCA is suitable for secure attendance management systems requiring both scalability and advanced cryptographic protection.

3.3 Computational Performance Analysis

The computational performance of the proposed Lightweight Hybrid Post-Quantum Cryptographic Algorithm (LHPQCA) was evaluated based on three key metrics: CPU utilization, memory consumption, and throughput. The experiment was conducted using different attendance dataset sizes ranging from 100 to 10,000 records to analyze the scalability and efficiency of the proposed framework.

The experimental results presented in Table 4 indicate that CPU utilization increases proportionally with the number of processed records. For a small dataset containing 100 records, the system consumes only 12.4% CPU utilization, while processing 10,000 records increases CPU usage to 56.9%. This increase is expected because larger datasets require additional cryptographic operations, including encryption, key management, hashing, and homomorphic aggregation.

Memory consumption also increases gradually as the dataset size expands. The proposed framework requires 48.6 MB of memory for 100 records and reaches 138.2 MB for 10,000 records. The moderate memory growth demonstrates that LHPQCA maintains efficient resource utilization and remains suitable for deployment in resource-constrained environments.

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The throughput evaluation shows significant scalability improvement as the dataset size increases. The system achieves 14,515 records/s for 100 records and reaches a maximum throughput of 89,310 records/s for 10,000 records. This result indicates that the proposed framework can efficiently process large-scale attendance data while maintaining acceptable computational performance.

Compared with conventional cryptographic approaches, LHPQCA introduces additional computational operations due to post-quantum protection and privacy-preserving computation mechanisms. However, the resource consumption remains within practical limits. The results demonstrate that LHPQCA provides a favorable balance between security enhancement and computational efficiency, making it suitable for secure student attendance management systems requiring scalability and long-term cryptographic protection.

Table 3 Computational Performance Analysis

Dataset Size (Records)	CPU Utilization (%)	Memory Consumption (MB)	Throughput (Records/s)
100	12.4	48.6	14,515
500	16.8	55.3	45,126
1,000	21.7	63.8	61,958
5,000	38.5	91.6	85,034
10,000	56.9	138.2	89,310

5. CONCLUSION

This study proposed a Lightweight Hybrid Post-Quantum Cryptographic Algorithm (LHPQCA) for securing student attendance data through a combination of advanced cryptographic techniques, including symmetric encryption, post-quantum key protection, hashing, and privacy-preserving aggregation. The proposed framework was designed to address the limitations of conventional cryptographic approaches, particularly the vulnerability of existing public-key algorithms against future quantum computing attacks and the lack of secure analytical capabilities.

The experimental results demonstrate that LHPQCA provides a balanced trade-off between security and computational efficiency. The encryption and decryption performance evaluation shows that LHPQCA introduces moderate computational overhead compared with AES-256-GCM while maintaining better efficiency than RSA-2048. For a dataset size of 10,000 attendance records, LHPQCA requires 100 ms for encryption and 90 ms for decryption, compared with 120 ms and 110 ms for RSA-2048, respectively. These results indicate that the proposed algorithm can provide enhanced security protection without significantly reducing system performance.

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Furthermore, the computational performance analysis confirms the scalability of the proposed framework. The system achieves a throughput of 89,310 records/s while maintaining acceptable resource consumption with 56.9% CPU utilization and 138.2 MB memory usage for processing 10,000 attendance records. These findings demonstrate that LHPQCA is capable of supporting large-scale attendance management systems with efficient computational requirements.

Overall, the proposed LHPQCA framework successfully integrates quantum-resistant security, efficient encryption processing, and privacy-preserving data analytics into a unified solution. The results indicate that LHPQCA is a promising approach for future secure attendance systems requiring long-term data confidentiality, integrity protection, and scalability. Future research will focus on optimizing the algorithm implementation, evaluating performance on edge computing devices, and conducting security analysis against advanced quantum attack scenarios.

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