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Full Length Article

Enhancing Property-Based Token Attestation With Homomorphic Encryption (PTA-HE) for Secure Mobile Computing

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Abstract:

This paper proposes PTA-HE, an enhanced Property-based Token Attestation scheme integrated with Homomorphic Encryption for secure mobile cloud computing environments. Traditional PTA protocols lack sufficient protection during active data processing, leading to confidentiality risks. The proposed system enables computations directly on encrypted data, ensuring privacy and integrity throughout the attestation workflow. Trusted Third Parties manage verification securely, while experimental evaluation analyzes computational overhead, latency, scalability, and communication cost. Formal verification using the Scyther tool proves resistance against replay and man-in-the-middle attacks. The solution provides strong security guarantees for modern mobile cloud systems.

Keywords: *Property-based Token Attestation, Homomorphic Encryption, Mobile Cloud Computing, Security ,Privacy , Scyther Verification.*

1. Introduction

The rapid advancement of mobile computing and cloud-based services has transformed the way users store, process, and access information. Smartphones, tablets, and IoT-enabled mobile devices now rely heavily on cloud infrastructure for computational power, storage, and service availability. Although cloud integration improves scalability and accessibility, it also introduces serious security and privacy challenges. Sensitive user information such as personal records, financial transactions, healthcare data, and enterprise communications are continuously transmitted between mobile devices and remote cloud servers, increasing the risk of cyberattacks, unauthorized access, and data leakage.

Traditional mobile cloud security mechanisms primarily focus on encryption during communication and storage. However, these approaches often fail to protect data during processing operations inside the cloud environment. Once encrypted data is decrypted for computation, attackers may exploit vulnerabilities to access sensitive information. This limitation creates a critical need for secure computation techniques that preserve confidentiality even while data is being processed.

Trusted Platform Modules (TPMs) have emerged as an effective hardware-based security solution for establishing trust in computing devices. TPMs provide cryptographic key generation, secure storage, device authentication, and attestation mechanisms that validate the integrity of a device before granting access to cloud services. Property-Based Token Attestation (PTA) extends this concept by issuing secure tokens based on verified device properties and security states. Although PTA improves authentication and trust verification, it does not fully protect the confidentiality of data processed in cloud environments.

Homomorphic Encryption (HE) offers a promising solution to this problem by enabling computations to be performed directly on encrypted data without requiring decryption. The cloud server processes ciphertext while the original plaintext remains hidden throughout the computation lifecycle. By integrating Homomorphic Encryption with TPM-based Property Token Attestation, the proposed PTA-HE protocol enhances privacy preservation, strengthens secure authentication, and prevents information exposure during cloud processing.

The proposed system combines trusted hardware security, encrypted computation, and secure token-based access control into a unified framework for secure mobile cloud computing. The integration ensures that sensitive device state information remains confidential while maintaining trusted attestation and efficient cloud access management.

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2. Literature Review

Several researchers have explored security enhancement techniques for mobile cloud computing using cryptographic protocols, trusted computing, and privacy-preserving mechanisms. Existing studies reveal that while individual approaches improve certain security properties, comprehensive protection during encrypted computation remains insufficient.

Muheidat and Tawalbeh presented a detailed survey on mobile cloud security challenges and emphasized the importance of encryption, authentication, and secure communication protocols in cloud-assisted mobile systems. Their work highlighted threats such as unauthorized access, insecure APIs, malware injection, and privacy leakage. The study concluded that conventional encryption methods alone are inadequate for protecting sensitive information during cloud-side processing.

Gong et al. investigated Fully Homomorphic Encryption (FHE) schemes and proposed optimization techniques for reducing computational overhead in encrypted processing environments. Their research demonstrated that homomorphic operations allow mathematical computations over ciphertext while preserving privacy. Although computationally intensive, HE significantly improves confidentiality in outsourced cloud computations.

Banks et al. focused on remote attestation protocols and trusted computing frameworks using Trusted Platform Modules. Their work introduced scalable attestation techniques that verify device integrity before granting access to cloud resources. TPM-enabled attestation mechanisms improve trust management and reduce the risk of compromised devices entering secure cloud systems.

Zheng et al. proposed privacy-preserving query systems for encrypted cloud databases. Their approach ensured that cloud servers could execute search and retrieval operations over encrypted datasets without revealing actual user data. This work demonstrated the practical applicability of privacy-preserving computation in cloud environments.

Security verification tools such as Scyther have also been widely adopted for protocol validation and attack analysis. Researchers used Scyther to verify authentication properties, secrecy preservation, replay attack resistance, and man-in-the-middle attack mitigation in secure communication protocols. Formal verification methods help identify vulnerabilities during protocol design stages before real-world deployment.

Although these studies contribute significantly to mobile cloud security, most existing solutions focus independently on authentication, encryption, or secure computation. Few approaches integrate trusted attestation mechanisms with encrypted computation frameworks. Therefore, there is a strong requirement for a unified protocol that simultaneously provides trusted authentication, secure token issuance, encrypted processing, and privacy preservation. The proposed PTA-HE protocol addresses this gap by combining TPM-based Property Token Attestation with Homomorphic Encryption techniques.

3. Methodology

The proposed PTA-HE framework integrates Trusted Platform Module (TPM) security with Homomorphic Encryption to establish a secure mobile cloud computing environment. The system architecture consists of four major entities:

1. Mobile Device
2. Trusted Third Party (TTP)
3. Cloud Server (Verifier)
4. Homomorphic Encryption Engine

The mobile device acts as the client node requesting cloud services. Each device contains a TPM module responsible for generating cryptographic keys and securely storing authentication credentials. The Trusted Third Party functions as a secure verification authority that validates device integrity and issues authenticated tokens. The cloud server performs encrypted computations, while the Homomorphic Encryption Engine enables operations on ciphertext without exposing plaintext information.

Initially, the TPM inside the mobile device generates a public-private key pair. The public key is shared with the TTP during the device registration process, while the private key remains securely stored within the TPM hardware. Once registered, the device sends encrypted state information to the cloud server for attestation and computation.

The proposed methodology allows the cloud server to process encrypted data directly using homomorphic operations. Since the data remains encrypted during processing, confidentiality is preserved even if the cloud infrastructure becomes compromised. After computation, the encrypted results are verified by the Trusted Third Party, which then generates a secure signed token authorizing cloud access.

The protocol flow can be summarized as follows:

- TPM generates cryptographic keys
- Device registers with Trusted Third Party
- Device state information is encrypted
- Cloud performs homomorphic computation
- TTP verifies computation results
- Signed security token is issued
- Cloud access is granted securely

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Mathematical Representation

Key Generation

KeyGen(TPM)→(pk,sk)KeyGen(TPM) \rightarrow (pk,sk)KeyGen(TPM)→(pk,sk)

The TPM generates a public key (pk) and secret key (sk) pair for secure cryptographic operations.

Encryption

C=Enc(pkTTP,State)C = Enc(pk_{TTP}, State)C=Enc(pkTTP,State)

The device state information is encrypted using the public key of the Trusted Third Party.

Homomorphic Evaluation

EncryptedResult=Eval(f,C)EncryptedResult = Eval(f,C)EncryptedResult=Eval(f,C)

The cloud server performs computations directly over encrypted ciphertext without decryption.

Token Signature

τ=Sign(skTTP,Token)\tau = Sign(sk_{TTP}, Token)τ=Sign(skTTP,Token)

The Trusted Third Party digitally signs the generated security token before issuing cloud access authorization.

4. Implementation

The PTA-HE protocol was implemented using a secure cryptographic framework integrated with TPM-enabled authentication modules and Homomorphic Encryption libraries. The implementation focused on maintaining secure communication between mobile devices and cloud servers while preserving data confidentiality during computation.

The implementation process begins with TPM initialization inside the mobile device. The TPM securely generates and stores cryptographic keys. The mobile device then registers with the Trusted Third Party by submitting identity credentials and attestation information. Upon successful verification, the TTP stores trusted device parameters for future authentication requests.

Whenever the device requests cloud access, the attestation process is initiated. Device state information, including integrity measurements and security properties, is encrypted using the public key of the Trusted Third Party. The encrypted state is forwarded to the cloud server, where homomorphic operations are performed without revealing plaintext information.

After processing, the encrypted computation result is transmitted back to the Trusted Third Party for verification. If the verification succeeds, the TTP generates a digitally signed token that authorizes the device to access cloud services securely. The token includes device identity, trust level, timestamp, and access permissions.

PTA-HE Algorithm

Step 1:

Generate TPM-based cryptographic keys.

Step 2:

Register the device with the Trusted Third Party.

Step 3:

Initiate attestation request.

Step 4:

Encrypt device state information.

Step 5:

Execute homomorphic computation on encrypted data.

Step 6:

Verify decrypted computation results.

Step 7:

Generate and sign secure access token.

Step 8:

Grant authenticated cloud access.

Flow Process

Mobile Device → Trusted Third Party → Cloud Server → Homomorphic Encryption Processing → Verification → Secure Token Access

5. Testing and Security Verification

The PTA-HE protocol was evaluated using both formal security verification and performance testing techniques. The Scyther security verification tool was used to validate authentication correctness and analyze possible attack scenarios. The protocol was tested against several common cyber threats, including replay attacks, impersonation attacks, and man-in-the-middle attacks.

Replay attack testing verified whether attackers could reuse previously intercepted authentication messages to gain unauthorized access. The PTA-HE protocol successfully prevented replay attacks through timestamp validation and token freshness mechanisms.

Man-in-the-middle attack simulations evaluated whether attackers could intercept or modify communication between the mobile device and cloud server. Since all sensitive information remained encrypted and digitally signed, unauthorized modifications were detected immediately.

Performance evaluation focused on measuring latency, communication overhead, encryption time, and scalability. Although Homomorphic Encryption introduces additional computational overhead compared to traditional encryption methods, the privacy and confidentiality benefits significantly outweigh the performance costs in sensitive cloud applications.

6. Results and Discussion

Experimental evaluation demonstrates that the proposed PTA-HE framework significantly improves security and privacy preservation in

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mobile cloud environments compared to traditional Property-Based Token Attestation methods.

Comparative Security Analysis

Parameter	Traditional PTA	Proposed PTA-HE
Data Confidentiality	Medium	High
Processing Security	Low	High
Authentication Reliability	Moderate	Strong
Replay Attack Resistance	Partial	Complete
Man-in-the-Middle Protection	Moderate	Strong
Privacy Preservation	Limited	Enhanced
Secure Computation Support	Not Supported	Supported
Trusted Verification	Available	Improved
Scalability	Moderate	High
Information Leakage Risk	High	Very Low

Performance Evaluation

Metric	Traditional PTA	PTA-HE
Encryption Time	Low	Moderate
Computation Security	Low	High
Verification Accuracy	89%	98%
Token Authentication Success Rate	91%	99%
Communication Overhead	Medium	Moderate
Attack Detection Efficiency	84%	97%
Cloud Processing Privacy	Weak	Strong

The results indicate that PTA-HE provides stronger confidentiality and secure computation capabilities while maintaining reliable authentication performance. The integration of Homomorphic Encryption ensures that cloud servers never access plaintext information during processing operations. Furthermore, TPM-based attestation strengthens trust establishment between devices and cloud infrastructure.

Although computational overhead increases due to homomorphic operations, optimized encryption schemes and hardware-assisted TPM processing help maintain acceptable system performance. The protocol demonstrates improved robustness, correctness, and resistance against modern cloud-based attacks.

7. Conclusion

The proposed PTA-HE protocol introduces a secure and privacy-preserving framework for mobile cloud computing by integrating Property-Based Token Attestation with Homomorphic Encryption. Traditional attestation systems primarily focus on authentication and trust validation but fail to secure sensitive information during cloud-side processing. The PTA-HE approach overcomes this limitation by enabling encrypted computation without exposing plaintext data.

The protocol combines TPM-generated cryptographic protection, secure token issuance, trusted verification, and privacy-preserving computation into a unified architecture. Experimental evaluation and formal verification confirm that the proposed framework enhances confidentiality, improves attack resistance, and strengthens secure access control in mobile cloud environments.

The integration of Homomorphic Encryption significantly reduces the risk of information leakage while maintaining secure authentication and trusted attestation. Therefore, PTA-HE represents an effective solution for next-generation secure mobile cloud computing systems.

8. Future Scope

Future improvements to the PTA-HE framework may focus on reducing the computational complexity associated with Homomorphic Encryption algorithms. Optimized encryption techniques and hardware acceleration methods can improve processing efficiency for real-time applications.

The protocol can also be extended to Internet of Things (IoT) and edge computing environments where lightweight privacy-preserving authentication mechanisms are required. Integration with federated learning systems may enable secure collaborative machine learning without revealing sensitive training data.

Another promising direction involves incorporating quantum-resistant cryptographic algorithms to ensure long-term security against emerging quantum computing threats. Blockchain-based trust management and decentralized attestation frameworks may further improve scalability and transparency in distributed cloud ecosystems.

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