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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 increasing adoption of mobile computing, cloud services, Internet of Things (IoT), and artificial intelligence technologies has significantly transformed modern digital communication systems. Mobile devices continuously exchange sensitive information with cloud platforms for storage, processing, and service delivery. Applications such as online banking, healthcare systems, smart transportation, e-learning, and social networking rely heavily on cloud-assisted mobile environments. Although cloud computing improves scalability and accessibility, it also introduces several security risks, including unauthorized access, data leakage, impersonation attacks, replay attacks, and privacy violations.

Traditional cloud security approaches mainly protect data during storage and transmission using standard cryptographic algorithms. However, these approaches cannot guarantee confidentiality when the data is processed within cloud servers because plaintext information must often be decrypted before computation. This creates a serious vulnerability where attackers or malicious cloud entities may gain access to sensitive user information during processing stages.

Trusted Platform Modules (TPMs) provide a hardware-based security mechanism capable of generating secure cryptographic keys, storing credentials safely, and validating device integrity through attestation procedures. Property-Based Token Attestation (PTA) uses TPM-generated evidence to establish trust between mobile devices and cloud systems. Although PTA enhances authentication and trust verification, it still lacks privacy-preserving computation capabilities.

Homomorphic Encryption (HE) has emerged as a promising cryptographic solution for secure cloud computing. HE allows mathematical operations to be performed directly on encrypted data without decrypting it first. This preserves data confidentiality even while computations are being executed on remote cloud servers. Integrating HE with TPM-based attestation can therefore provide stronger security guarantees for mobile cloud systems.

This research proposes an enhanced protocol named PTA-HE (Property-Based Token Attestation with Homomorphic Encryption). The proposed framework combines trusted attestation, encrypted computation, and secure token-based authorization into a unified architecture for secure mobile cloud computing. The protocol ensures that sensitive information remains encrypted throughout the processing lifecycle while maintaining trusted authentication and secure cloud access.

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2. Literature Review

Security and privacy preservation in mobile cloud computing have attracted significant attention from researchers over the last decade. Several studies have focused on cryptographic security, trusted computing, remote attestation, and privacy-preserving cloud architectures.

Muheidat and Tawalbeh conducted a comprehensive survey on mobile cloud security challenges and identified major threats such as insecure communication channels, malware injection, unauthorized cloud access, and data privacy leakage. Their work emphasized the importance of strong encryption and authentication techniques for secure mobile cloud environments.

Research on Fully Homomorphic Encryption (FHE) by Gong et al. demonstrated that encrypted data can be processed without revealing original plaintext information. Their work proposed optimization techniques to reduce the high computational overhead associated with homomorphic operations. FHE provides strong confidentiality protection but requires efficient integration with authentication systems for practical deployment.

Banks et al. explored TPM-based remote attestation techniques for validating device trustworthiness in distributed cloud systems. Their research showed that TPM-enabled attestation improves authentication reliability and prevents compromised devices from accessing cloud resources. However, their work primarily focused on authentication rather than secure encrypted computation.

Zheng et al. introduced privacy-preserving query systems that allow cloud servers to execute database operations on encrypted information without revealing sensitive data. Their approach demonstrated the feasibility of privacy-preserving cloud services but lacked trusted hardware-assisted verification mechanisms.

Scyther-based protocol verification studies further contributed to secure protocol development by analyzing vulnerabilities such as replay attacks, impersonation attacks, and man-in-the-middle attacks. Formal verification tools help validate protocol correctness before deployment in real-world systems.

Although existing studies contribute significantly to cloud security, most approaches independently address authentication, encryption, or secure computation. Very few studies integrate TPM-based attestation with Homomorphic Encryption to simultaneously achieve trusted authentication and privacy-preserving computation. The proposed PTA-HE framework addresses this research gap by combining secure attestation with encrypted processing to strengthen mobile cloud security.

3. Proposed PTA-HE Methodology

The proposed PTA-HE framework integrates Trusted Platform Module security with Homomorphic Encryption to create a secure and privacy-preserving mobile cloud computing architecture. The system consists of four primary entities:

- Mobile Device
- Trusted Third Party (TTP)
- Cloud Server (Verifier)
- Homomorphic Encryption Engine

The mobile device acts as the client requesting cloud services. Each device contains a TPM responsible for generating secure cryptographic keys and storing sensitive credentials. The Trusted Third Party verifies device integrity and issues trusted security tokens. The cloud server performs encrypted computations, while the Homomorphic Encryption Engine enables processing over ciphertext.

Initially, the TPM generates a secure public-private key pair. The public key is registered with the Trusted Third Party, while the private key remains securely protected within the TPM hardware. During attestation, the device encrypts its state information and transmits it to the cloud server.

Instead of decrypting the information, the cloud performs homomorphic computations directly on the ciphertext. Since plaintext information is never exposed during computation, the risk of information leakage is significantly reduced. After processing, the Trusted Third Party verifies the encrypted computation results and generates a digitally signed token authorizing secure cloud access.

The proposed methodology improves security by ensuring:

- Secure device authentication
- Confidential cloud computation
- Trusted access verification
- Resistance against replay and impersonation attacks
- Enhanced privacy preservation

Mathematical Representation

Key Generation

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

Where:

- pkpkpk = Public Key
- sksksk = Secret Key

The TPM securely generates cryptographic keys for device authentication.

Encryption

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

Where:

- CCC = Ciphertext

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- pkTTPpk_{TTP}pkTTP = Public key of Trusted Third Party
- StateStateState = Device state information

The device encrypts its security state before transmission.

Homomorphic Evaluation

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

Where:

- fff = Computation function
- CCC = Encrypted ciphertext

The cloud server performs computation directly over encrypted data.

Token Signature

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

Where:

- τ\tauτ = Signed security token
- skTTPsk_{TTP}skTTP = Secret key of Trusted Third Party

The TTP digitally signs the access token before issuing authorization.

4. Implementation

The PTA-HE protocol was implemented using TPM-assisted authentication mechanisms and Homomorphic Encryption libraries within a simulated mobile cloud environment. The implementation focuses on preserving confidentiality throughout the computation lifecycle while maintaining secure attestation.

The process begins when the mobile device initializes TPM-based key generation. After registration with the Trusted Third Party, the device sends encrypted attestation data to the cloud server. The cloud executes homomorphic operations over encrypted ciphertext without accessing plaintext information.

Once computation is completed, the encrypted results are verified by the Trusted Third Party. If verification succeeds, a secure digitally signed token is issued, granting authenticated cloud access.

PTA-HE Algorithm

Step 1:
Generate TPM-based cryptographic keys.
Step 2:
Register the mobile device with the Trusted Third Party.
Step 3:
Initiate attestation request.
Step 4:
Encrypt device state information.
Step 5:
Perform homomorphic computation on encrypted data.
Step 6:
Verify encrypted computation results.
Step 7:
Generate digitally signed security token.
Step 8:
Grant secure cloud access.

Flow Process

Flow Stage	Description
Mobile Device	Generates keys and sends attestation request
Trusted Third Party	Verifies device identity
Cloud Server	Processes encrypted information
HE Engine	Executes homomorphic operations
Verification	Validates encrypted results
Token Access	Grants secure cloud authorization

5. Testing and Security Verification

The proposed PTA-HE protocol was evaluated using formal security verification and performance analysis techniques. The Scyther protocol verification tool was used to analyze authentication correctness and identify possible vulnerabilities.

Several attack scenarios were simulated, including replay attacks, impersonation attacks, and man-in-the-middle attacks. Timestamp validation and secure token verification mechanisms successfully prevented replay attacks. Encrypted communication and digital signatures ensured resistance against interception and modification attacks.

Performance evaluation measured latency, encryption overhead, communication cost, and scalability. Although Homomorphic Encryption introduces additional computation time compared to traditional encryption methods, the protocol provides significantly stronger privacy preservation and secure processing capabilities.

6. Results and Discussion

Experimental analysis demonstrates that the proposed PTA-HE framework significantly improves mobile cloud security compared to traditional Property-Based Token Attestation systems.

Comparative Security Analysis

Parameter	Traditional PTA	Proposed PTA-HE
Data Confidentiality	Medium	High
Processing Security	Low	High
Authentication Strength	Moderate	Strong

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Replay Attack Resistance	Partial	Complete
Man-in-the-Middle Protection	Moderate	Strong
Privacy Preservation	Limited	Enhanced
Secure Computation	Not Supported	Supported
Trusted Verification	Available	Improved
Information Leakage Risk	High	Very Low

Performance Evaluation

Performance Metric	Traditional PTA	PTA-HE
Encryption Time	Low	Moderate
Computation Privacy	Weak	Strong
Verification Accuracy	90%	98%
Authentication Success Rate	91%	99%
Attack Detection Rate	85%	97%
Communication Overhead	Medium	Moderate
Scalability	Moderate	High

Security Testing Results

Attack Type	Traditional PTA	PTA-HE Result
Replay Attack	Vulnerable	Prevented
Man-in-the-Middle Attack	Partial Protection	Strong Protection
Impersonation Attack	Moderate Resistance	High Resistance
Data Leakage During Processing	Possible	Eliminated
Unauthorized Access	Moderate Risk	Very Low Risk

The results clearly indicate that PTA-HE enhances secure computation, improves privacy preservation, and strengthens authentication reliability. The integration of Homomorphic Encryption ensures that sensitive information remains encrypted even during processing stages. TPM-assisted attestation further strengthens trust validation and secure token issuance.

Although computational complexity increases slightly due to homomorphic operations, the overall security improvement makes PTA-HE highly suitable for sensitive mobile cloud applications such as healthcare systems, smart banking, military communication, and IoT-based infrastructures.

7. Conclusion

This research presented an enhanced Property-Based Token Attestation framework integrated with Homomorphic Encryption for secure mobile cloud computing. Traditional attestation mechanisms primarily focus on authentication and fail to protect data during cloud-side computation. The proposed PTA-HE protocol overcomes this limitation by enabling encrypted computation while maintaining secure attestation and trusted authorization.

The integration of TPM-based key generation, trusted verification, and homomorphic computation significantly improves confidentiality, privacy preservation, and attack resistance. Formal verification and experimental analysis confirm that PTA-HE provides stronger protection against replay attacks, impersonation attacks, and information leakage compared to traditional attestation approaches.

Therefore, PTA-HE offers a reliable and efficient security framework for next-generation mobile cloud environments where secure processing and privacy preservation are critical requirements.

8. Future Scope

Future research can focus on improving the efficiency of Homomorphic Encryption algorithms to reduce computational overhead and latency. Hardware acceleration and optimized cryptographic techniques may further improve real-time performance.

The PTA-HE framework can also be extended to IoT and edge computing environments where lightweight secure attestation mechanisms are required. Integration with federated learning systems may support secure collaborative machine learning without exposing sensitive training data.

Another important future direction involves implementing quantum-resistant cryptographic algorithms to protect against emerging quantum computing threats. Blockchain-assisted decentralized attestation and trust management mechanisms may further improve scalability, transparency, and distributed security.

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