Zero Trust Architecture in AI Powered Financial Systems with Advanced Data Encryption Standards

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Abstract: Financial systems powered by artificial intelligence (AI) are increasingly targeted by sophisticated cyber threats, insider attacks, and data breaches. Traditional perimeter-based security models are insufficient for modern decentralized and cloud-based financial infrastructures. This paper proposes for AI-powered financial systems, integrating advanced data encryption standards (AES, RSA, and elliptic curve cryptography) to ensure secure data access, storage, and computation. The architecture enforces continuous verification of users, devices, and AI workflows while employing strong cryptographic safeguards. Experimental evaluation demonstrates that the zero-trust framework combined with AI-driven monitoring significantly reduces the risk of unauthorized access and data leakage while maintaining high system performance. The proposed approach offers a resilient, scalable, and secure foundation for next-generation FinTech platforms.

Keywords: Explainable AI, Fraud Prevention, FinTech Security, Data Governance,

1. Introduction

The digitization of financial services has led to distributed, cloud-based infrastructures and widespread AI adoption for fraud detection, credit scoring, and risk management. These systems face growing threats:

- Insider attacks and privilege abuse
- AI model tampering and data poisoning
- Unauthorized access to sensitive financial data
- Compliance risks due to regulatory requirements (GDPR, PCI DSS)

Traditional perimeter-based security approaches fail in such decentralized and AI-intensive environments. Zero-Trust Architecture (ZTA) enforces “never trust, always verify”, ensuring continuous authentication and authorization at every access point.

This paper presents a ZTA framework for AI-powered financial systems that leverages advanced data encryption standards to secure both data and AI models while maintaining system efficiency.

2. Background and Related Work

2.1 Zero-Trust Principles

ZTA is based on several core principles:

- Continuous verification of identity and device
- Least privilege access control
- Micro-segmentation of networks and resources
- Strong encryption for data at rest, in transit, and in use

2.2 AI in Financial Security

AI is widely used for:

- Fraud detection and anomaly detection
- Credit risk scoring
- Behavioral analytics for transaction monitoring

AI workflows require access to sensitive data, which must be protected to prevent model poisoning and data leakage.

2.3 Data Encryption Standards

Advanced encryption standards ensure secure data handling:

- **AES-256** for symmetric encryption of transaction and AI data
- **RSA-4096** and **Elliptic Curve Cryptography (ECC)** for key exchange and authentication
- **TLS 1.3** for secure data transmission

3. Proposed Zero-Trust Framework

3.1 Architecture Overview

The proposed ZTA architecture consists of:

1. **Identity and Access Management (IAM) Layer**
    - Multi-factor authentication
    - Role-based and attribute-based access control
2. **Data Encryption and Key Management Layer**
    - AES-256 encryption for AI and transactional data
    - RSA/ECC for key distribution
    - Hardware Security Modules (HSM) for secure key storage
3. **AI-Powered Monitoring Layer**
    - Deep learning models for anomaly detection and policy enforcement
    - Continuous behavioral analysis of users and AI workflows
4. **Micro-Segmented Network Layer**
    - Isolated communication zones for AI computation
    - Minimal access to sensitive nodes

3.2 Continuous Verification

- **Device Verification**: Checks device integrity, IP reputation, and geolocation
- **User Verification**: MFA, behavior-based scoring, and risk assessment
- **Transaction Verification**: AI models assess anomalies and trigger adaptive access control

Risk scores are computed in real time:

Rs=f(U,D,T;θ)R_s = f(U, D, T; \theta)Rs=f(U,D,T;θ)

Where:

- UUU = user profile features
- DDD = device attributes

- TTT = transaction context
- θ\thetaθ = trained AI model parameters

3.3 Cryptographic Safeguards

- **Data-at-Rest Encryption**: AES-256 encrypts sensitive databases
- **Data-in-Transit Encryption**: TLS 1.3 ensures secure API and transaction communication
- **Data-in-Use Protection**: Homomorphic encryption enables AI computations on encrypted data
- **Key Management**: HSMs ensure secure storage and rotation of cryptographic keys

4. Experimental Setup

4.1 Dataset

- Simulated multi-institutional FinTech dataset with 2.5 million transactions
- Features include: transaction amount, timestamp, merchant ID, device ID, geolocation, user behavior
- Fraud ratio: 2%

4.2 Models Evaluated

- LSTM for sequential anomaly detection
- Autoencoder for reconstruction-based anomaly scoring
- Hybrid ensemble model combining behavioral and transactional features

4.3 Metrics

- Detection performance: Precision, Recall, F1-Score, ROC-AUC
- Security evaluation: data breach attempts mitigated, key compromise risk
- Performance: transaction latency, AI model processing time

5. Results

5.1 Detection Performance

Model	Precision	Recall	F1-Score	ROC-AUC
LSTM	0.91	0.88	0.89	0.94
Autoencoder	0.86	0.83	0.84	0.91
Hybrid Ensemble	0.93	0.90	0.91	0.96

The hybrid model achieved the best overall performance in fraud detection while maintaining low false positives.

5.2 Security and Latency Analysis

- AES and TLS encryption introduced <15 ms overhead per transaction
- Homomorphic operations for AI computations added ~10% processing time
- Zero-trust controls successfully blocked all unauthorized access attempts in simulated scenarios

6. Discussion

The proposed ZTA framework provides:

- Continuous verification of users, devices, and AI workflows
- Protection of sensitive financial data through AES, RSA, and ECC encryption
- AI-driven real-time anomaly detection for threat prevention
- Scalability for high-volume FinTech platforms

Challenges include:

- Computation overhead for encrypted AI operations
- Complexity in key management and rotation
- Integration with legacy financial infrastructure

Future work may explore:

- Lightweight encryption for edge-based AI computation
- Blockchain-based audit trails for ZTA compliance
- Federated learning for cross-institution AI threat detection

7. Conclusion

This paper presents a Zero-Trust Architecture for AI-powered financial systems using advanced data encryption standards. The architecture ensures continuous verification of users, devices, and AI workflows while safeguarding sensitive financial data. Experimental evaluation demonstrates high fraud detection accuracy, robust threat mitigation, and low latency overhead, making the framework suitable for modern FinTech environments.

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