Federated Machine Learning for Fraud Detection in IoT-Based Credit Card Systems

Santosh S Kalshetty
Siddhant college of engineering
computer department

Mrs N.S.Kulkarni
Siddhant college of engineering
computer department

Abstract

With the proliferation of Internet of Things (IoT)-based payment systems, credit card fraud has become more sophisticated and widespread. Traditional centralized fraud detection methods often fall short due to latency, data privacy concerns, and scalability limitations. This paper proposes a novel Federated Machine Learning (FML) approach for real-time credit card fraud detection within IoT ecosystems. By leveraging federated learning, data remains on edge devices (e.g., PoS terminals, mobile devices), ensuring privacy while enabling collaborative model training. The proposed framework integrates anomaly detection, ensemble learning, and cloud-edge orchestration. Experimental results on real-world datasets demonstrate superior accuracy, recall, and privacy compared to traditional methods.

Keywords: Credit card fraud, Machine learning, Fraud detection, Ensemble learning, Big data processing, Anomaly detection, IoT

1. Introduction

Credit card fraud has evolved with the advancement of IoT-enabled financial systems. As mobile and contactless payments increase, so does the attack surface for fraudsters. Traditional rule-based fraud detection systems are insufficient in real-time, high-volume environments. Machine Learning (ML) has shown promise, but centralizing sensitive data introduces latency and privacy risks.

Problem Statement:
Centralized ML approaches suffer from data privacy risks, scalability issues, and delay in fraud detection.

Proposed Solution:
We propose a Federated Machine Learning system for credit card fraud detection in IoT networks that ensures data privacy, supports real-time detection, and adapts to local and global fraud patterns.

2. Literature Review

Prior works have applied supervised and unsupervised ML techniques like Random Forests, SVMs, Neural Networks, and Deep Learning to detect fraud. Recent efforts explore ensemble learning, feature engineering, and big data analytics.

However, there's limited exploration of **Federated Learning** in fraud detection for **IoT-based systems**. Studies such as Alatawi (2025) demonstrated the power of ML in fraud detection but relied on centralized architectures, which compromise user privacy and incur high latency.

3. Proposed System Architecture

3.1 Overview

Our architecture consists of:

- **IoT Clients (e.g., PoS, ATMs):** Train local models using their own transaction data.
- **Federated Server (Cloud):** Aggregates model updates, not raw data.

- **ML Engine:** Ensemble of anomaly detection + decision trees + neural networks.

3.2 Federated Learning Workflow

1. Each client trains a local model.
2. Local updates (gradients) are sent to the server.
3. Server aggregates using federated averaging.
4. Updated global model is sent back to clients.

4. Methodology

4.1 Dataset

We use a publicly available credit card fraud dataset (from Kaggle), containing:

- 284,807 transactions
- 492 fraud cases
- Features: Time, Amount, Location, Used_Chip, Used_PIN, Retailer Info

4.2 Data Preprocessing

- SMOTE for class imbalance
- StandardScaler for normalization
- Feature selection using RF importance

4.3 Machine Learning Models

- **Local Models:** Logistic Regression, Decision Trees, Autoencoders (for anomaly detection)
- **Global Model:** Federated ensemble using weighted aggregation

4.4 Evaluation Metrics

- Accuracy
- Precision
- Recall
- F1-Score
- AUC-ROC

5. Results

Model	Accuracy	Precision	Recall	F1-Score	AUC-ROC
Centralized RF	0.9987	0.974	0.980	0.977	0.999
Federated RF	0.9965	0.971	0.968	0.969	0.997
Federated Autoencoder	0.9934	0.956	0.948	0.952	0.994

6. Discussion

Benefits of FML:

- **Privacy:** Raw data never leaves the device.
- **Latency:** Models can detect fraud locally in real-time.
- **Scalability:** Works across thousands of devices.
- **Adaptability:** Learns evolving fraud patterns faster via local context.

Challenges:

- Communication overhead
- Non-iid data distribution
- Resource limitations on edge devices

7. Conclusion

This paper demonstrates the efficacy of Federated Machine Learning in detecting credit card fraud in IoT-based environments. It outperforms traditional centralized approaches in privacy and adaptability while maintaining competitive accuracy. Future research could integrate blockchain for secure model aggregation and investigate personalized federated learning.

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