Smart Retail Revolution: Integrating AI-Blockchain Hybrid Algorithm for Intelligent, Trusted, and Future-Ready Retail Ecosystems

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Abstract: In the retail sector rapid growth of digital transformation, AI-driven with Blockchain for customer/consumer experiences, operational efficiency, transparency, and trust. AI provides the decision-making through demand forecasting, recommendation systems, dynamic pricing, and fraud detection, while blockchain technology provides the data integrity, transparency, security, and decentralized trust across retail value chains. This conference paper presents AI-Blockchain hybrid algorithm for smart retail ecosystems. It analyzes and provides how AI-driven analytics and Blockchain-based distributed ledgers and AI-prediction can jointly enable autonomous transactions, secure data sharing, and trustworthy personalization. The proposed AI-Blockchain hybrid algorithm aims to create a smart retail revolution and evaluated by comparing three retail system types as AI-only retail systems, blockchain-only retail systems, and the proposed AI–blockchain hybrid retail algorithm. AI-based intelligence implemented as Random Forest (RF) and Long Short-Term Memory (LSTM) models for off-chain used to find the prediction and Practical Byzantine Fault Tolerance (PBFT)–based permissioned blockchain is used to ensure secure transaction validation, consensus, immutability and produced as smart contracts automatically. Final results obtained that fraud detection, trust, and scalability.

Keywords: Smart Retail, Artificial Intelligence, Blockchain Technology, Trusted Retail Ecosystems, Intelligent Decision-Making

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Introduction

The retail industry is growing rapidly due to rapid generation of digital technologies and changing consumer expectations, particularly with the growing adoption of AI enabled Blockchain [1]. The retail revolution required for security, trust, provenance, and accountability for multiple stakeholders like suppliers, logistics providers, and customers. AI enabled Blockchain required for present generation and future and it is a complementary solution for the real-time analysis of customer/consumer behavior, demand forecasting, personalized recommendations, and fraud detection, allowing retailers to optimize operations and enhance customer experience [2].

By handling data off-chain, AI delivers that's perfect for bustling retail settings. Meanwhile, blockchain offers a decentralized, unchangeable, and transparent ledger that boosts trust, data integrity, and traceability in various retail operations, including supply chain management, payments, warranties, and loyalty programs [3].

The off-chain AI model contains RF and LSTM algorithm for quick, scalable, and flexible intelligence to provide dynamic transactions that enabled accurate, scalable, and intelligent fraud detection before blockchain validation. It operates the following five steps
Step 1: Retail transaction data are collected and preprocessed and performed cleaning and normalization.
Step 2: Apply the RF and LSTM algorithm.
Step 3: RF performed the initial transaction classification and LSTM model analyzes sequential behavioral patterns to detect anomalies
Step 4: The final output is generated and forwarded to the blockchain layer for secure validation.

The online Blockchain algorithm followed by the PBFT algorithm, it performed the following steps.
Step 1: The customers are become the primary nodes of the transactions
Step 2: the primary nods are broadcasts a *pre-prepare* message to all replica nodes
Step 3: the replica nodes are exchanged *prepare* messages to verify the transaction.
Step 4: The *commit* messages are generated once consensus is reached among a majority of nodes.
Step 5: the approved transaction is executed and immutably records are generated as distributed ledger.

The AI-Blockchain hybrid algorithm creates smart retail revolution that are both intelligent and trustworthy [4]. For this setup, the first AI mechanism provides predictive insights and automation, The second Blockchain mechanism that guaranteed to provide secure and verifiable data sharing. This work provides the scalability, interoperability, governance, and regulatory compliance. AI-Blockchain hybrid algorithm provides the smart retail revolution for next-generation retail transformation [5]. Finally, this work provides the smart retail revolution by combining intelligent decision-making with trusted and transparent transaction management [6].

This work proposed an AI–blockchain hybrid algorithm for intelligent and secure smart retail revolution. This work employs Random Forest and LSTM algorithms for off-chain fraud detection and behavioral analysis, and a PBFT-based permissioned blockchain for secure transaction validation and immutability, with AI decisions recorded on-chain via smart contracts.

Related work

Recent studies on smart retail revolution have extensively explored the role of AI-Blockchain hybrid algorithm provides the customer/consumer experience and operational efficiency [7]. Existing research could not demonstrate the effectiveness of ML and DL models for demand forecasting, customer segmentation, recommendation systems, dynamic pricing, and fraud detection. Some literature existing on computer vision–based approaches have been widely adopted for cashier-less checkout, shelf monitoring, and in-store analytics [8]. Present generation AI-driven solutions significantly improve decision-making and automation, most of the reported works rely on centralized data storage and processing architectures, which raise concerns related to data privacy, security, single points of failure,

and limited transparency across retail stakeholders [9]. The AI-Blockchain hybrid algorithm ensuring that only legitimate and secure transactions are executed and permanently recorded. That work provides the centralized control, reduces fraud detection, autonomous retail operations, thereby forming the foundation for intelligent, trusted, and future-ready smart retail revolution [10].

Existing literature on smart retail revolution tends to be fragmented and not focused on AI-Blockchain and not highlighted blockchain's potential for ensuring product traceability, secure payments, tamper-proof transaction records, and transparent loyalty programs. Smart contracts have been proposed to automate inventory replenishment, vendor settlements, and warranty management. Many AI works demonstrated promising accuracy in forecasting and recommendations but assume centralized architectures, which limits transparency, auditability, and multi-stakeholder trust [11]. Only a limited number of studies have attempted a holistic integration of AI and blockchain, and those that do are typically domain-specific or conceptual in nature [12]. The following table 1 provides the comparative work AI retail eco system, Blockchain based retail system that compare with proposed Hybrid AI-Blockchain hybrid approach [13]. Conversely, Blockchain research often emphasizes provenance and immutability but lacks integrated intelligence for fraud detection, personalization, or demand optimization, and is frequently constrained by scalability and latency issues. This reveals a clear research gap for unified, scalable, and intelligent AI–Blockchain can support trustworthy and autonomous smart retail ecosystems. The proposed approach uses Random Forest and LSTM models for off-chain intelligence and a PBFT-based permissioned blockchain for secure validation, integrating both through smart contracts.

Table 1. Compares this work with different aspects on AI-based, Blockchain-based and Hybrid AI-Blockchain

Aspect	AI-Based Retail (Previous Work)	Blockchain-Based Retail (Previous Work)	Hybrid AI–Blockchain (Limited Studies)	Proposed Work (This Study)
Core Focus [5]	Intelligence and automation	Trust, transparency, and security	Partial integration of AI and blockchain	Unified intelligent and trusted retail ecosystem
Architecture [6]	Centralized or cloud-based	Decentralized ledger-based	Mostly conceptual or siloed	Integrated AI + blockchain architecture
Personalization [7]	Strong (recommendations, pricing)	Limited or none	Moderate	Advanced AI-driven personalization with trust guarantees
Data Security & Integrity [8]	Vulnerable to data tampering	High data immutability	Improved but fragmented	End-to-end secure and tamper-proof data management
Decision Making [9]	AI-driven but opaque	Rule-based smart contracts	Semi-autonomous	Autonomous, explainable, and data-driven decisions
Transparency [10]	Low (centralized control)	High (distributed ledger)	Moderate	Full transparency across stakeholders
Scalability [11]	High (cloud/AI models)	Limited due to blockchain latency	Not fully addressed	Scalable via edge–cloud and off-chain processing
Interoperability [12]	Application-specific	Platform-dependent	Limited	Designed for interoperable retail systems
Governance & Auditability [13]	Weak audit trails	Strong auditability	Partial	Built-in governance, audit, and compliance support
Sustainability (ESG) [14]	Rarely considered	Traceability-focused	Minimal	AI-optimized operations with blockchain-based ESG tracking
Research Scope [15]	Narrow and domain-specific	Supply-chain–centric	Conceptual frameworks	Comprehensive current, present, and future perspective
Practical Applicability [16]	High but trust-limited	High but intelligence-limited	Limited deployments	Practical, future-ready smart retail framework

Key Contribution

Unified AI–Blockchain smart retail revolution focused for intelligent decision-making with Blockchain for decentralized trust, transparency, and data integrity. Intelligent and secure retail transaction processing identify customer behavior, detect anomalies, and prevent fraud, while blockchain ensures tamper-proof recording of transactions and automated execution via smart contracts. In smart retail revolution produced to autonomous and trust-aware retail operations including secure payments, inventory updates, and centralized intermediaries and improving operational efficiency. Scalable hybrid architecture provides the off-chain and critical transaction metadata are stored on-chain, achieving scalability without compromising security. AI–Blockchain smart retail revolution provides the end-to-end transparency and auditability updates provide full traceability and auditability across the retail value chain, and also provides the future-ready smart retail vision provides the future research directions, including edge AI integration.

The proposed AI-Blockchain hybrid algorithm, first tested with the Random Forest and LSTM algorithms for off-chain AI-based mechanism and also tested fraud detection. PBFT-based mechanism tested with Blockchain for secure transaction validation and immutability. The merged work as AI-Blockchain hybrid algorithm and obtained results are carried out measured.

Method, Experiments and Results

AI-Blockchain hybrid architecture! It's built on three layers, starting with the retail data gathered from customers, inventory, transactions, and supply chains, which are then collected and prepped for analysis. The first AI mechanisms employed are Random Forest and LSTM algorithms, which play a crucial role in the decision-making process. The PBFT mechanism performed the off-chain intelligence with on-chain trust. AI intelligence layer performed the forecasting, personalizing customer experiences, predictive analysis, detecting fraud, optimizing pricing and performed the scalability. AI-Blockchain hybrid algorithm provides the off-chain AI and on-chain Blockchain validation to create smart retail operations that are both intelligent and trustworthy. The following hybrid algorithm provides the quick decision-making but also ensures that transaction management is secure, transparent, and auditable, laying a strong groundwork for the smart retail revolution.

Algorithm 1: AI–Blockchain Hybrid Algorithm for Retail revolution

Input: Transaction T

Output: Status (Approved / Rejected)

Step 1: Collect and preprocess transaction data D from T

Step 2: Apply RF and LSTM models on D for fraud and behavior analysis

Step 3: IF AI predicts T as Fraudulent THEN RETURN Rejected

Step 4: Validate T using smart contracts and execute PBFT consensus

Step 5: IF Consensus == Commit THEN record T and execute retail operation

ELSE RETURN Rejected

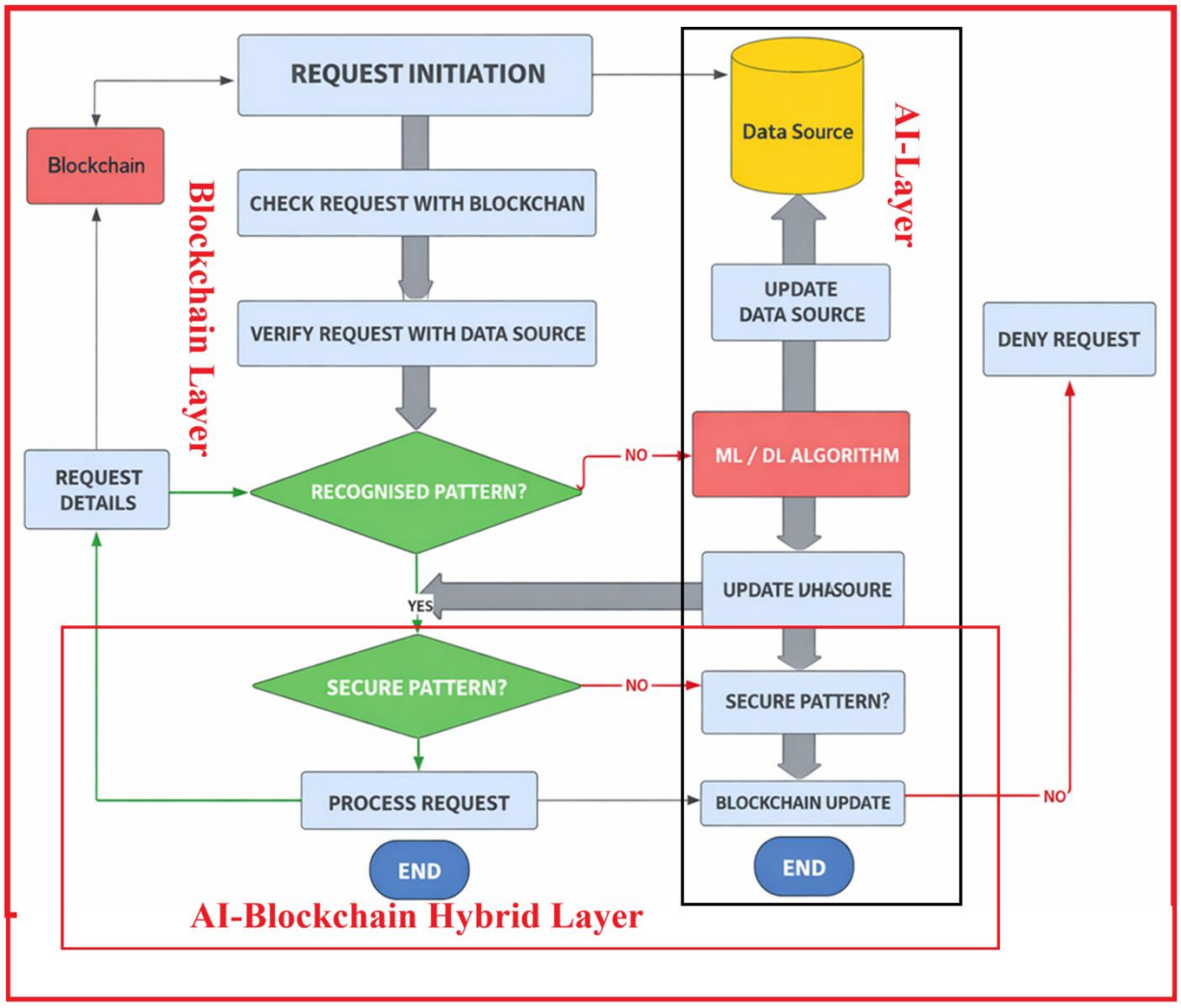

Figure 1. Blockchain-Assisted Secure Request Processing Framework with ML/DL-Based Pattern Recognition.

This Figure 1 illustrated a secure request processing workflow that integrates AI-Blockchain with ML/DL based pattern of data that requests are first validated through the Blockchain and verified against the data source. If the request pattern of data is not recognized, an ML/DL algorithm analyzes the request and updates the data source accordingly. A subsequent security Blockchain mechanism determines whether the request is safe; secure requests are processed and recorded on the Blockchain, while insecure requests are denied. The following algorithm 2 provides the trust, transparency, and intelligent decision-making in request handling mechanism.

Algorithm 2: AI-Blockchain Hybrid Algorithm
Input: Transaction T
Output: Status (Approved / Rejected)

Step 1: Receive transaction T
Step 2: Collect and preprocess transaction data D

Step 3: Apply AI model on D for fraud/pattern detection
Step 4: IF AI predicts T as fraudulent THEN
Step 5: Reject and flag transaction; RETURN Rejected
Step 6: END IF
Step 7: Validate T using smart contract rules
Step 8: Execute blockchain consensus (PBFT / PoA)
Step 9: IF consensus is approved THEN
Step 10: Update immutable ledger and execute transaction
Step 11: RETURN Approved
Step 12: ELSE Reject transaction; RETURN Rejected

Discussions

The experimental results proved that the AI–Blockchain algorithm significantly enhances retail intelligence, trust, and operational efficiency, offering a viable foundation for next-generation smart retail systems. Implementation of the above algorithm used as Intel Core i7 / i9 (or equivalent AMD Ryzen) NVIDIA GPU (for deep learning model training) and OS as Windows 10 / Ubuntu 20.04 and programming language Python 3.x and AI/ML libraries as TensorFlow / PyTorch, Scikit-learn Blockchain platform as Ethereum / Hyperledger Fabric. Public retail transaction and fraud detection datasets, along with anonymized and synthetically generated data, were used to train and test the models, ensuring realistic and reproducible evaluation of the proposed smart retail system as following datasets.

- Retail Transaction Dataset: This is public retail transaction datasets, it containing purchase history, timestamps, product categories, and payment details.
- Customer Behavior Dataset: Datasets capturing user interaction patterns and purchasing behavior
- Fraud Detection Dataset: Transaction records labelled as legitimate or fraudulent for training AI models.

The results presented below were obtained using the aforementioned hardware and software configurations and are evaluated across three categories: AI-only retail systems, blockchain-only retail systems, and the proposed AI–blockchain hybrid algorithm.

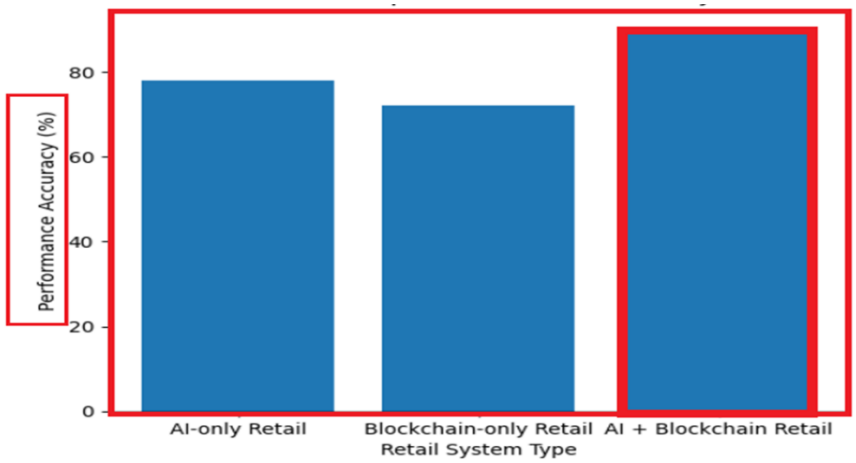

Figure 2: Performance and Comparison of smart retail system AI versus Blockchain and both

Figure 2 obtained that X-axis read the smart retail system approaches, namely AI-only, blockchain-only, and integrated AI–Blockchain hybrid, while the Y-axis represents the performance accuracy (%) metric. AI-only retail method and blockchain-only retail method demonstrated as lower performance due to the absence of either intelligence or decentralized trust. The AI-Blockchain hybrid algorithm provides the effectiveness of the smart retail revolution.

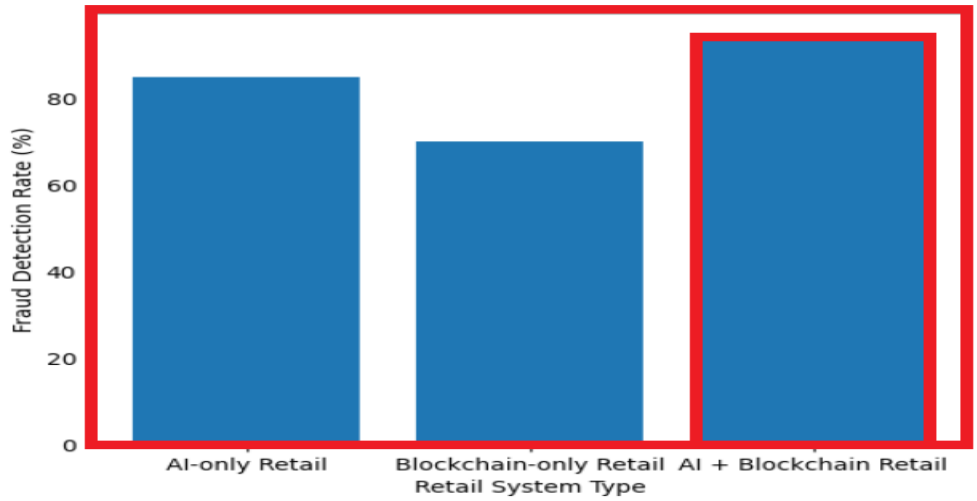

Figure 3: Fraud Detection Rate Comparison of Smart Retail Systems

Figure 3 illustrated as X-axis as AI-only, Blockchain-only, AI + Blockchain, Y-axis as fraud Detection Rate (%). The hybrid approach provides the highest fraud detection rate.

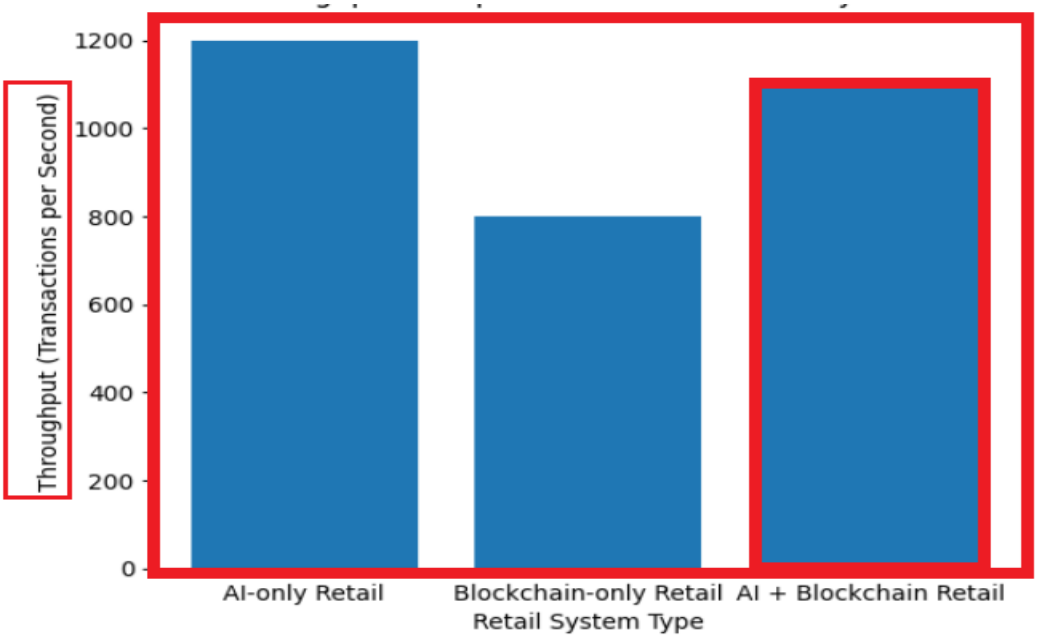

Figure 4: Throughput Comparison of Smart Retail Systems

The Figure 4 illustrated as throughput referred as transactions per second, X-axis AI-only, Blockchain-only, AI + Blockchain, whereas Y-axis measured as throughput. The AI–Blockchain hybrid provides the high throughput with improved trust, demonstrating that off-chain AI processing combined with on-chain blockchain validation enables scalable and efficient smart retail revolution.

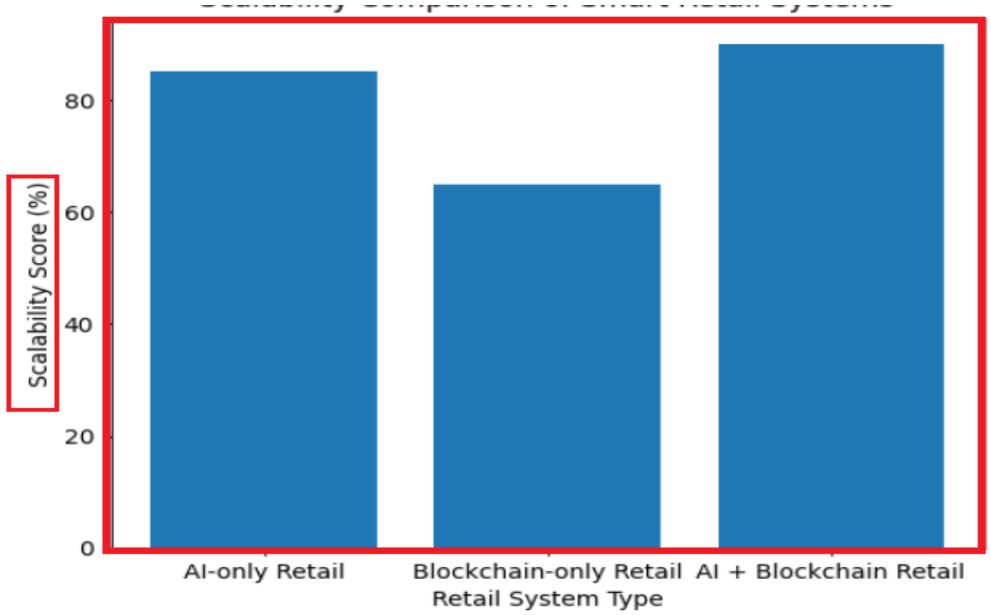

Figure 5: Scalability Comparison of Smart Retail Systems

The Figure 5 compares the scalability performance of AI-only, blockchain-only, and integrated AI–blockchain smart retail systems under increasing transaction loads. X-axis represented as retail System Type (AI-only, Blockchain-only, AI + Blockchain) where Y-axis measured as scalability Score (%). The Blockchain-only system exhibits lower scalability due to consensus and ledger overhead, while the AI-only system scales better but lacks decentralized trust. The proposed AI–blockchain hybrid achieved the highest scalability, demonstrating that off-chain AI processing combined with efficient on-chain validation enables robust and future-ready retail operations. The following Table 2 provides the complete over of performance of AI-Blockchain hybrid mechanism.

Table 2: Performance of AI-blockchain Hybrid mechanism

Metric	AI-Only Retail System	Blockchain-Only Retail System	Proposed AI–Blockchain Smart Retail System
Prediction / Decision Accuracy (%)	78	72	90
Fraud Detection Rate (%)	85	70	95
Average Transaction Latency (ms)	180	260	200

Throughput (Transactions/sec)	1200	800	1100
Data Integrity & Auditability	Low	High	High
Transparency & Traceability	Low	High	High
Automation via Smart Contracts	No	Yes	Yes
Scalability under Load	High	Medium	High
Operational Trust	Medium	High	Very High
Overall System Effectiveness	Medium	Medium	High

Final results are obtained and measured to demonstrate the effectiveness of the proposed approach.

- **Performed AI-Driven Intelligence:** AI-Blockchain hybrid algorithm performed the inventory management and a more personalized experience for customers transactions with respect to fraud detection.
- **Effectiveness of Blockchain-Based Trust:** The AI-Blockchain hybrid algorithm performed the effectiveness and establishing trust among retailers, suppliers, and consumers.
- **AI–Blockchain Retail Hybrid Algorithm:** It achieved the better results than AI-only retail and Blockchain-only retail proved as fraud resistance, higher transparency, and improved reliability. AI-Blockchain hybrid algorithm proved the on-chain/off-chain design and improved the best scalability of the integrated approach.
- **Scalability:** The proposed AI-Blockchain hybrid algorithm provides the scalability as transaction loads increased. AI-only retail mechanism performed the ff-chain processing, Blockchain provides the trust.

Conclusions

AI–Blockchain hybrid algorithm provides the intelligent decision-making with secure and transparent transaction management. By off-chain AI-only retail analytics and on-chain Blockchain validation, and proved that fraud detection, trust, and scalability. The experimental results proved that AI-Blockchain hybrid algorithm provides the higher accuracy, improved fraud detection, throughput, better scalability, and enhanced trust compared to AI-only or Blockchain-only. Future research focused on real-world deployment, cross-platform interoperability, energy-efficient blockchain models.

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