International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 06 | June - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Effective Management for Blockchain-Based Agri-Food Supply Chains Using Deep Reinforcement Learning

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Abstract - The agri-food industry faces persistent challenges in managing supply chains, including inefficiencies, traceability issues, and compliance concerns. Leveraging blockchain technology offers transparency, yet optimizing decision-making remains a challenge. This research explores the integration of deep reinforcement learning (DRL) with blockchain-based agri-food supply chains to enhance efficiency, transparency, and compliance. The study focuses on developing DRL models, integrating them with blockchain, optimizing operations, ensuring quality control, and evaluating performance.

Key Words: *Agri-Food Supply Chains, Blockchain Technology, Deep Reinforcement Learning, Decision-Making Optimization, Transparency, Compliance*

1.INTRODUCTION

The agri-food industry faces numerous complexities, including fragmented processes, information asymmetry, and trust issues among stakeholders. These challenges often lead to inefficiencies, lack of transparency, and compromised food safety. Traditional supply chain management struggles to address these issues comprehensively.

Blockchain technology emerges as a promising solution due to its immutable and decentralized nature, enabling transparent and secure data sharing among multiple parties in the supply chain. By leveraging blockchain, stakeholders can track the journey of food products from farm to table, ensuring authenticity and quality. However, the effective management of blockchain-based agri-food supply chains requires intelligent decision-making mechanisms to optimize various aspects such as logistics, inventory management, and quality control. Deep reinforcement learning, a subset of machine learning, offers a potent solution to navigate the complexities of these supply chains by enabling autonomous learning and decision-making based on trial-and-error experiences.

Discuss the role of blockchain in revolutionizing transparency, traceability, and trust within agri-food supply chains. Highlight its benefits in ensuring food authenticity, reducing fraud, and enhancing consumer confidence. Address the existing inefficiencies and challenges in traditional supply chain management, including information silos, lack of real-time data, and trust issues among stakeholders. Explore how the integration of DRL techniques with blockchain technology can enhance supply chain management. Discuss potential applications such as predictive analytics for demand forecasting, dynamic pricing, route optimization, and quality control.

This research aims to explore the synergies between blockchain technology and deep reinforcement learning techniques to optimize agri-food supply chains. By integrating these cutting-edge technologies, the aim is to enhance transparency, traceability, and decision-making processes, thereby revolutionizing the way the agri-food industry manages its supply chains.

2. Body of Paper

2.1 Proposed System

The proposed system aims to revolutionize agri-food supply chains by integrating **Deep Reinforcement Learning (DRL)** with **Blockchain technology**. This hybrid framework ensures intelligent decision-making and secure, transparent tracking across every stage of the supply chain.

Key Objectives:

- **Transparency & Traceability**: Using blockchain for immutable record-keeping of product movement and origin.
- **Optimized Decision-Making**: Employing DRL agents to dynamically manage logistics, inventory, and resource allocation.
- **Real-time Monitoring**: Utilizing IoT sensors to collect environmental and operational data, feeding it into the DRL model.
- **Cost & Waste Reduction**: Enhancing efficiency by reducing transportation delays, resource misallocation, and spoilage.

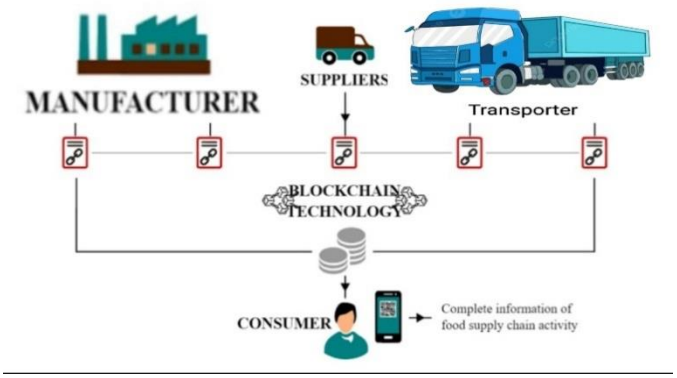

Fig -1: SYSTEM ARCHITECTURE

2.2 Working

The system comprises multiple interconnected modules working in synergy:

1. Data Collection Layer:
- IoT sensors deployed across farms, warehouses, and transportation units gather data like temperature, humidity, GPS location, and stock levels.

2. Blockchain Layer:
- All collected data and supply chain events are hashed and stored in blocks.
- This ensures **tamper-proof traceability** and allows stakeholders to verify the product's history.

3. DRL-Based Decision Engine:
- A reinforcement learning agent observes the current state (e.g., inventory level, demand forecast, weather conditions).
- Based on rewards and penalties, it learns optimal strategies for:
  - Route planning
  - Resource allocation
  - Inventory restocking

4. Smart Contracts:
- Automate supply chain processes (e.g., trigger payments or insurance claims upon delivery or verified crop damage).

5. User Interface:
- Visual dashboards display analytics for farmers, transporters, and retailers.
- Screens allow stakeholders to input data and query product provenance.

2.3 Algorithms

1. Deep Reinforcement Learning (DRL) Algorithm:
- Algorithm Type: Actor-Critic / DQN (Deep Q-Network)
- Input: State (inventory, demand, environmental data)
- Action: Choose logistics route, reorder quantity, allocation strategy
- Reward: Minimize cost, time, spoilage; maximize satisfaction
- Learning Process:
  - Agent explores and exploits environment
  - Learns a policy to maximize cumulative rewards

2. Blockchain Consensus Mechanism:
- Algorithm Used: Proof of Work / Proof of Authority (based on implementation)
- Ensures that new supply chain transactions are securely validated and appended to the ledger.

3. Genetic Algorithm (for comparison/optimization):
- Used for: Route optimization, scheduling under constraints.
- Mimics biological evolution with selection, crossover, and mutation to find near-optimal solutions.

3. RESULTS

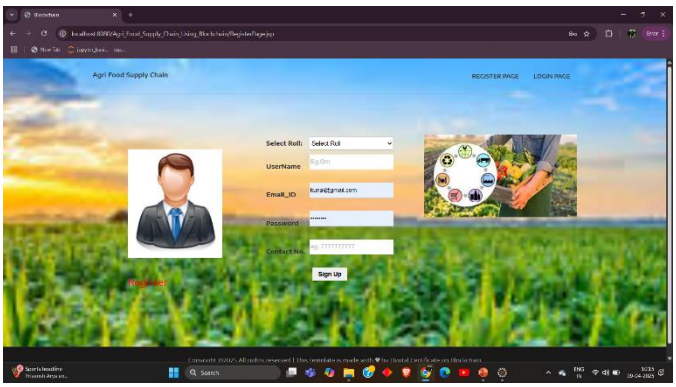

Fig -3.1: Home Page

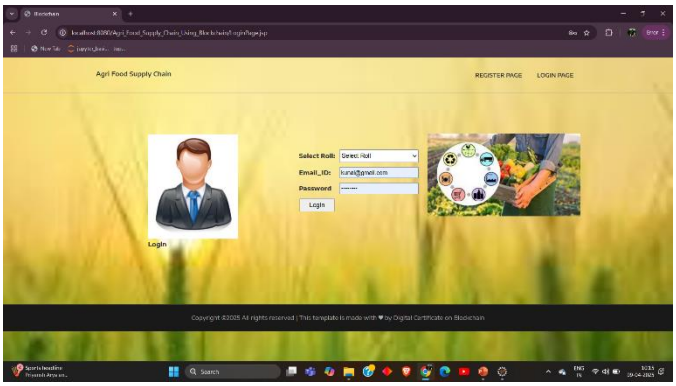

Fig -3.2: Login Page

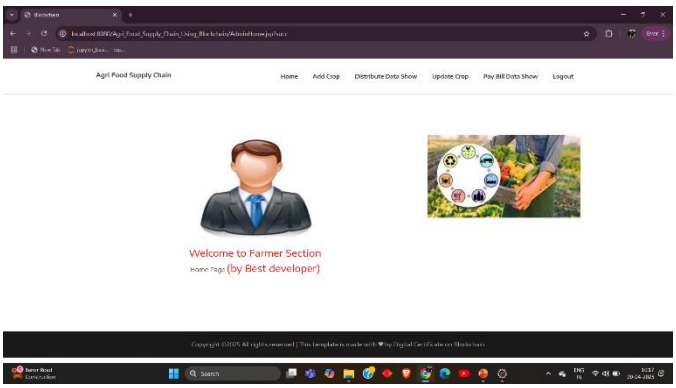

Fig -3.3: Farmer Page

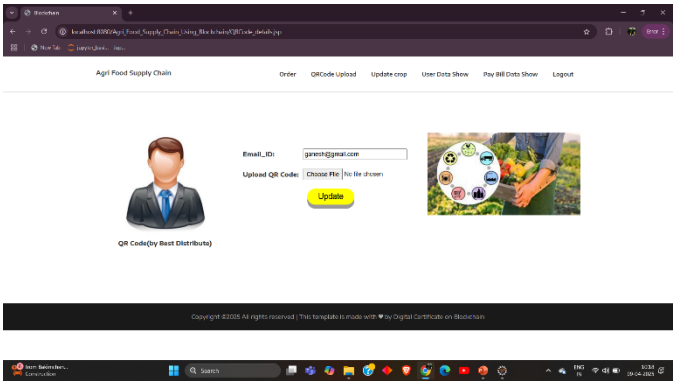

Fig -3.4: Distributor Page

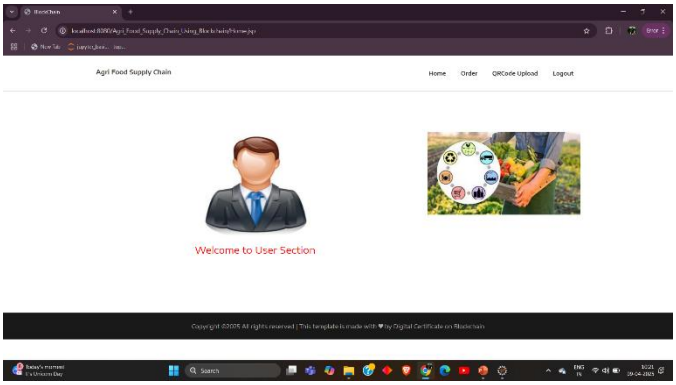

Fig -3.5: User Page

4. CONCLUSIONS

The integration of deep reinforcement learning (DRL) into blockchain-based agri-food supply chains is poised to revolutionize industry practices by enhanc ing efficiency, transparency, and decision-making capabilities. This integration is anticipated to yield significant improvements in supply chain operations, op timizing resource allocation, ensuring transparent and immutable traceability, and enabling real-time adaptive decision-making. The conclusive findings are expected to showcase the transformative potential of DRL-blockchain synergy in fortifying compliance, improving key performance metrics, and fostering scala bility. Ultimately, this innovative approach lays the groundwork for widespread adoption, paving the way for a more resilient, efficient, and trustworthy agri food supply chain ecosystem.

5. FUTURE SCOPE

Scalability Across Sectors: Expanding the framework to cover other agricultural sectors such as livestock management, dairy supply chains, and fisheries. Integration with AIoT (Artificial Intelligence of Things): Real-time decision making using data from IoT sensors combined with AI models to monitor cli mate, crop health, and logistics. Federated Learning for Data Privacy: Leveraging decentralized AI training methods to ensure sensitive agricultural data remains secure while still bene f iting from machine learning advancements. Cross-Chain Interoperability: Allowing multiple blockchain networks to com municate and share verified data across global supply chains. Policy and Governance Modeling: Embedding smart policies within smart contracts to enforce sustainability, fair trade, and food safety regulations.

6. REFERENCES

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