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Agricultural Supply Chain Management System Using Blockchain

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Abstract — The agricultural sector faces persistent challenges related to transparency, traceability, fraud, and inefficiency in traditional supply chain management systems. These conventional systems depend heavily on centralized intermediaries, manual processes, and paper-based record keeping, all of which introduce significant risks of data manipulation, delays, and income disparities for farmers. This paper presents an Agricultural Supply Chain Management System built on blockchain technology to address these critical shortcomings. The proposed system is implemented as a web application using Java EE (JSP and Servlets) with a MySQL database backend, providing distinct functional modules for three primary actors: Farmers, Suppliers, and Administrators. Blockchain hashing using SHA-512 and data protection via AES encryption are integrated to ensure the integrity and confidentiality of every transaction in the supply chain. When the Administrator approves a transaction, the system automatically generates a blockchain hash record composed of six chained block values, thereby creating an immutable and tamper-proof audit trail. The proposed system eliminates the need for trusted third-party intermediaries, enhances the security and transparency of crop advertisement and trade, and directly empowers farmers by giving them access to a digital marketplace. Experimental results confirm that the system performs reliably, and the blockchain-backed transaction records provide end-to-end traceability from farm to final buyer. The system offers significant advantages over existing solutions in terms of security, performance, and operational transparency.

Keywords — Blockchain, Agricultural Supply Chain, SHA-512, AES Encryption, Smart Contract, Traceability, Transparency, Java EE, Distributed Ledger, Food Safety.

I. INTRODUCTION

The agricultural supply chain is one of the most complex networks in the global economy, involving multiple stakeholders including farmers, aggregators, processors, distributors, retailers, and consumers. The inefficiencies embedded in traditional agricultural supply chains result in significant food losses, income inequality for smallholder farmers, and reduced consumer trust due to the inability to verify product provenance and quality.

Blockchain technology, originally introduced as the underlying infrastructure for Bitcoin, has rapidly evolved into a transformative platform applicable across diverse sectors. A blockchain is a decentralized, distributed ledger that records transactions in a sequence of immutable blocks. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data, making retroactive alteration computationally infeasible. This tamper-evident structure is precisely what makes blockchain well-suited for supply chain management, where data authenticity and traceability are paramount.

In the existing agricultural supply chain landscape, farmers often lack the market information necessary to negotiate fair prices, and centralized platforms create single points of failure susceptible to data corruption and fraud. Intermediaries extract a disproportionate share of the value generated along the chain, leaving primary producers underpaid. Additionally, the absence of reliable traceability mechanisms makes it difficult to identify the source of contamination during food safety incidents, endangering consumer health and imposing significant economic costs on all chain participants.

The system proposed in this paper directly addresses these challenges by providing a blockchain-backed web application that connects farmers and suppliers through a transparent, secure, and efficient digital marketplace. The Administrator module acts as a governance layer that oversees and approves transactions, while simultaneously triggering blockchain hash generation to record approved events permanently. The use of SHA-512 hashing ensures cryptographic strength, and AES encryption protects sensitive transactional data against unauthorized access. Together, these mechanisms deliver a supply chain management solution that is secure, scalable, and equitable for all participants.

II. LITERATURE SURVEY

A substantial body of research has emerged over the past decade examining the application of blockchain technology to agricultural and food supply chains. These studies collectively highlight the technology's potential to address longstanding issues of traceability, fraud, transparency, and stakeholder trust.

Salah et al. (2019) proposed an Ethereum-based framework for soybean traceability that leverages smart contracts to automate and validate each stage of the supply chain from seeding to delivery. Their work demonstrated that blockchain could eliminate the need for centralized authorities while maintaining high data integrity and reliability [1].

Casino et al. (2020) implemented a distributed, trustless architecture for food supply chain traceability in the dairy sector. Their system featured fully functional smart contracts deployed on a local private blockchain, and demonstrated that upstream and downstream supply chain members could store traceability records without relying on fragmented or paper-based systems [2].

Ronaghi (2020) presented a blockchain maturity model for agricultural supply chains, using the SWARA multi-criteria decision method to rank blockchain dimensions by importance. Findings indicated that smart contracts, IoT integration, and transaction records were the highest priority dimensions for agricultural applications [3].

Paliwal et al. (2020) conducted a systematic literature review using the Emerging Technology Literature Classification Level (ETLCL) framework. Their analysis confirmed that traceability and transparency are the primary benefits of blockchain in sustainable supply chain management, and noted a sharp increase in research activity since 2017 [4].

Chen et al. (2021) integrated a Deep Reinforcement Learning-based Supply Chain Management (DR-SCM) method with a blockchain-based agri-food supply chain framework. Their simulation experiments confirmed that the blockchain framework provided reliable traceability, while DR-SCM outperformed heuristic and Q-learning methods in profit optimization [5].

Awan et al. (2020) designed a smart blockchain model for agricultural food supply chains that eliminates the need for third-party trust intermediaries and gives equal market opportunities to all stakeholders, regardless of whether they are familiar with one another [6].

Manvizhi et al. (2025) explored blockchain adoption in Indian agriculture using Binance Smart Chain (BSC) to enhance scalability and reduce transaction confirmation times compared to Ethereum-based implementations. Their work highlighted the growing importance of updatable smart contracts in dynamic agri-food environments [7].

Osuagwu et al. (2024) developed a decentralized agricultural supply chain management system with peer-to-peer data structures and crypto wallet-based authentication, which ensured that dishonest market participants could not tamper with product provenance records [8].

Surya and Manohar (2024) proposed an integrated blockchain framework that combined crop yield prediction, secure supply chain management, and demand forecasting. Their three-phase approach demonstrated that predictive analytics, when combined with blockchain, could significantly improve supply chain planning and market efficiency [9].

Collectively, these studies confirm that blockchain technology offers a compelling solution to the persistent challenges of agricultural supply chain management. However, many existing implementations focus on Ethereum-based architectures or IoT-integrated platforms that require significant infrastructure investment. The proposed system in this paper addresses these gaps by offering a lightweight, Java EE-based web implementation suitable for deployment in resource-constrained environments typical of developing agricultural economies.

III. EXISTING SYSTEM AND LIMITATIONS

The conventional agricultural supply chain management system relies on centralized databases and manual, paper-based processes to track the flow of agricultural goods, financial transactions, and information between stakeholders. These systems are characterized by a heavy dependence on intermediaries such as brokers, aggregators, and wholesalers, who control market access and price discovery to the disadvantage of primary producers.

Farmers operating within these traditional systems have limited visibility into real-time market prices and buyer demand. This information asymmetry systematically disadvantages smallholder farmers, who must accept prices dictated by middlemen rather than negotiating based on accurate market intelligence. Furthermore, the centralized nature of these platforms makes them highly vulnerable to data manipulation, unauthorized modification of records, and fraudulent transactions.

Traceability is another critical failure of the existing system. When food safety incidents occur, the inability to quickly identify the source of contamination leads to broad, costly product recalls that affect entire supply chains rather than the specific batch responsible. This lack of granular traceability imposes substantial financial and reputational costs on legitimate producers.

The key disadvantages of the existing system are summarized as follows:

- Low Security: Centralized databases are single points of failure susceptible to cyberattacks, unauthorized data access, and internal fraud.
- Traceability Issues: Absence of an end-to-end audit trail makes it impossible to trace products back to their origin in real time.
- Low Performance: Manual workflows and paper-based reconciliation introduce significant delays in transaction settlement and dispute resolution.
- Regional Disparities: Farmers in remote areas have reduced access to market information and trading platforms, exacerbating rural income inequality.
- Lack of Transparency: Stakeholders cannot independently verify the accuracy of price, quality, or quantity claims made by intermediaries.
- High Intermediary Costs: The multi-layer intermediary structure extracts excessive transaction fees, reducing the net income available to farmers.

IV. PROPOSED SYSTEM

The proposed Agricultural Supply Chain Management System introduces a blockchain-integrated web application that enables direct and transparent trading between farmers and suppliers, governed by an administrative oversight layer. The core innovation of the system lies in its use of blockchain hashing to create an immutable transaction record at the point of administrative approval, ensuring that every approved trade event is permanently and verifiably recorded.

The system architecture is built using Java EE technologies, specifically JSP (JavaServer Pages) and Servlets for the presentation and controller layers, with a MySQL relational database for persistent storage. The blockchain module is implemented in Java and generates a chain of six cryptographic hash blocks for each approved transaction using the SHA-512 algorithm. AES symmetric encryption is applied to sensitive data fields to prevent unauthorized disclosure.

The system supports three distinct user roles, each with a dedicated functional interface:

Farmer Module: Registered farmers can log in to submit land details and crop cultivation information, post complaints regarding agricultural issues, receive expert farming tips from the administrator, and browse supplier crop advertisements to accept offers at negotiated prices.

Supplier Module: Registered suppliers can post crop purchase advertisements specifying title, crop name, required quantity, and an associated image. They can monitor the status of posted advertisements and receive price responses from farmers.

Administrator Module: The administrator oversees the entire system, viewing lists of registered farmers and suppliers, managing complaints, providing farming tips, and approving or rejecting transactions. Upon approval, the system automatically generates blockchain hash data that encodes the transaction details into an immutable six-block chain record.

The principal advantages of the proposed system are:

- Enhanced Security: SHA-512 hashing and AES encryption protect all transaction data against tampering and unauthorized access.
- Increased Transparency: All stakeholders can access a clear, verifiable record of transactions through the blockchain audit trail.
- Improved Performance: Automated workflows eliminate manual processing delays and reduce settlement times.
- Elimination of Intermediaries: The direct farmer-supplier marketplace removes unnecessary middlemen and associated costs.
- Sustainability: The digital platform reduces the environmental impact of paper-based record keeping.
- Scalability: The modular Java EE architecture supports future integration with additional technologies such as IoT sensors and machine learning models.

V. ALGORITHMS USED

A. SHA-512 Algorithm

The Secure Hash Algorithm 512 (SHA-512) is a member of the SHA-2 family of cryptographic hash functions, designed by the National Security Agency (NSA) and standardized by the National Institute of Standards and Technology (NIST). It produces a 512-bit (64-byte) fixed-size hash value from an input of arbitrary length, making it computationally infeasible to reverse-engineer the original input from the hash output alone.

SHA-512 was selected for the blockchain hashing module of this system because of its superior resistance to collision attacks, pre-image attacks, and second pre-image attacks compared to shorter hash functions such as SHA-256 or SHA-1. In the context of blockchain, these properties ensure that no two distinct transactions can produce the same hash value, and that altering any field in a recorded transaction will produce an entirely different hash, making tampering immediately detectable.

The SHA-512 computation proceeds through the following steps: (1) Message padding — the input is padded to a multiple of 1024 bits. (2) Initialization — eight 64-bit hash values are initialized with specific constants derived from the square roots of the first eight prime numbers. (3) Message schedule — the padded message is divided into 1024-bit blocks and expanded into 80 64-bit words using a message schedule function. (4) Compression — each block is processed through 80 rounds of bitwise operations including shifts, rotations, and modular additions, applied in conjunction with 80 round constants. (5) Final concatenation — the eight output values from the compression function are concatenated to produce the final 512-bit hash digest.

B. AES Algorithm

The Advanced Encryption Standard (AES) is a symmetric block cipher standardized by NIST in 2001 and widely recognized as the global standard for data encryption. AES operates on fixed-size data blocks of 128 bits and supports key lengths of 128, 192, or 256 bits. In the proposed system, AES is employed to encrypt sensitive transactional data stored in the database, ensuring that even if database records are accessed without authorization, the content remains confidential.

AES offers several critical properties that make it appropriate for this application: (1) It is a symmetric algorithm, enabling fast encryption and decryption with a single shared key. (2) It has been subjected to extensive public cryptanalysis and has no known practical attacks against properly implemented versions. (3) It is at least six times faster than Triple-DES while offering a significantly larger effective key space. (4) It is implementable in standard Java using the javax.crypto library without requiring external dependencies.

VI. SYSTEM ARCHITECTURE AND DESIGN

The system architecture follows a three-tier model comprising a presentation tier (JSP pages), a business logic tier (Java Servlets and POJOs), and a data tier (MySQL database with blockchain tables). This separation of concerns enhances maintainability and allows each tier to be independently scaled or modified without disrupting the others.

The database schema consists of six primary tables: userregistration (stores farmer and supplier account credentials and profile data), farmerdetails (records land size, crop type, water source, and land ownership details), adpost (stores supplier crop advertisements including crop name, quantity, image path, and acceptance status), compliant (records farmer-submitted complaints and their resolution status), farmingtips (stores expert agricultural guidance posted by the administrator), transactions (records every trade event with sender, receiver, type, and status), and blockchaintbl (stores the six-block blockchain hash record generated upon transaction approval).

The blockchaintbl table structure is particularly significant: each row contains the block ID, concatenated packet data, the number of blocks (fixed at 6), six separate hash block fields (block1 through block6), and a status field. This schema enables the system to store and retrieve the complete blockchain record for any approved transaction, providing full auditability.

The web interface was implemented using Bootstrap-based responsive HTML/CSS templates, ensuring accessibility across desktop and mobile browsers. JDBC (Java Database Connectivity) is used throughout the Servlet layer to interact with the MySQL database, with prepared statements employed consistently to prevent SQL injection vulnerabilities.

VII. IMPLEMENTATION

The implementation was carried out using the Eclipse IDE with an Apache Tomcat web server. The development process followed a module-by-module approach, beginning with user registration and authentication, followed by the farmer and supplier functional modules, and concluding with the administrator transaction approval and blockchain generation workflow.

The blockchain generation logic is encapsulated in the NoobChain class and the Block class. When the administrator approves a transaction, the system retrieves the transaction details from the transactions table and constructs an array of six data fields: block ID, sender ID, receiver ID, transaction type, transaction ID, and transaction date. These fields are passed to the NoobChain.doblockchain() method, which iteratively hashes the concatenated input data using SHA-512, linking each block's hash as the input seed for the subsequent block. The resulting chain of six SHA-512 hash values is then persisted to the blockchaintbl table, and the transaction status is updated from 'Processing' to 'Success'.

The AdTransactionProcess.jsp page orchestrates the transaction approval workflow, combining JDBC queries, the blockchain module, and database updates in a single coordinated operation. Upon completion, the page displays a structured table showing the block ID, packet data, number of blocks, all six block hash values, and the final status, providing the administrator with a complete view of the generated blockchain record.

File upload functionality for crop images was implemented using the Apache Commons FileUpload library, which handles

multipart HTTP requests from the supplier's advertisement posting form. Uploaded images are stored in a designated server-side directory and referenced by filename in the adpost table, allowing them to be displayed on the farmer-facing advertisement browsing interface.

VIII. DATABASE DESIGN

The relational database schema was designed to support all system operations with minimal redundancy and maximum referential integrity. The six tables are structured to capture the complete lifecycle of a transaction from initial user registration through crop advertisement, acceptance, transaction initiation, administrative approval, and final blockchain recording. Table I presents the schema of the blockchaintbl table, which is central to the blockchain implementation.

Table I: blockchaintbl Schema

Column Name	Data Type	Constraint
blockid	VARCHAR(45)	DEFAULT NULL
packetdata	VARCHAR(255)	DEFAULT NULL
noofblocks	VARCHAR(45)	DEFAULT NULL
block1–block6	VARCHAR(255)	DEFAULT NULL
status	VARCHAR(45)	DEFAULT NULL

IX. SYSTEM TESTING

System testing was conducted across five testing levels to ensure that the deployed application meets the functional, security, and performance requirements specified during the design phase.

Unit Testing: Individual modules including user registration, complaint posting, advertisement management, and blockchain generation were tested in isolation. Test cases validated all decision branches, input/output combinations, and error handling paths within each module.

Functional Testing: End-to-end functional tests verified that valid inputs produced expected outputs and that invalid inputs were appropriately rejected. All core use cases — including farmer registration and complaint submission, supplier advertisement posting, and administrator transaction approval — were tested against documented requirements.

Integration Testing: The interaction between the JSP presentation layer, Servlet business logic, and MySQL database was validated to ensure correct data flow across all module boundaries. The integration between the transaction processing servlet and the blockchain module was specifically tested to confirm that hash generation was triggered correctly upon approval events.

Performance Testing: Response times for key operations including blockchain hash generation, transaction approval, and database query execution were measured and found to be within acceptable limits for a web-based application under expected concurrent user loads.

Acceptance Testing: User acceptance tests confirmed that registered farmers, suppliers, and the administrator could complete their respective workflows without errors, and that all blockchain records were accurately generated and stored following transaction approval.

X. RESULTS AND DISCUSSION

The implemented system was deployed and tested on a local server environment running Apache Tomcat with MySQL 5.5. Across all test scenarios, the system demonstrated robust performance and reliable blockchain hash generation. Key observations from the experimental evaluation are summarized as follows.

The blockchain transaction module successfully generated six-block SHA-512 hash chains for all approved transactions. The hash values produced were consistent and unique for each distinct transaction dataset, confirming the collision-resistance property of SHA-512 in practice. A representative transaction record demonstrated that modifying any input field — such as the sender ID or transaction date — produced a completely different set of six block hashes, validating the tamper-evidence property of the implemented blockchain.

The farmer complaint management workflow operated correctly, with complaints submitted by farmers appearing in the administrator's queue and transitioning to 'Resolved' status following administrative action. Farming tips posted by the administrator were immediately visible in the farmer interface, demonstrating real-time data synchronization across user roles.

The supplier advertisement module correctly handled image uploads and persisted crop details to the adpost table. Farmers browsing the advertisement interface successfully retrieved and accepted offers, triggering the creation of a sale transaction record. The administrator's transaction list accurately reflected all pending transactions across complaint, advertisement, and sale categories, each tagged with the correct sender, receiver, type, and date information.

The system's security posture was evaluated by attempting direct database queries and unauthorized URL access. Prepared statements effectively neutralized SQL injection attempts, and session-based authentication prevented unauthorized access to role-specific pages. AES-encrypted data stored in the database was confirmed to be unreadable without the correct decryption key.

Table II: Comparison with Existing Systems

Feature	Existing System	Proposed System
Security	Low	High (SHA-512 + AES)
Traceability	Limited	Full (Blockchain)
Transparency	Opaque	End-to-end
Intermediaries	Many	Minimized
Transaction Speed	Slow (Manual)	Fast (Automated)
Data Integrity	Vulnerable	Tamper-proof

XI. FUTURE ENHANCEMENTS

While the current system successfully demonstrates the viability of a blockchain-based agricultural supply chain management platform, several directions for future enhancement have been identified.

The integration of Internet of Things (IoT) sensors at key stages of the supply chain — such as cold storage facilities, transportation vehicles, and retail distribution centers — would enable automated, real-time data capture and reduce the reliance on manual input. Each IoT event could be directly submitted to the blockchain, further strengthening the integrity and granularity of the audit trail.

The adoption of a public or consortium blockchain such as Ethereum or Hyperledger Fabric would extend the system's reach beyond a single administrative domain, enabling multiple independent organizations to participate in the supply chain without requiring mutual trust in a shared administrator. Smart

contract-based automation could replace the administrator approval step, reducing the system's dependence on a single trusted actor.

Predictive analytics and machine learning models for crop yield forecasting and demand prediction, as proposed by Surya and Manohar (2024), could be integrated to enable proactive supply chain planning. Price recommendation engines could further empower farmers by suggesting optimal selling prices based on market trends and historical transaction data.

A mobile application interface would improve accessibility for rural farmers who are more likely to use smartphones than desktop computers. Multilingual support would further reduce barriers to adoption in linguistically diverse agricultural regions.

XII. CONCLUSION

This paper presented an Agricultural Supply Chain Management System that leverages blockchain technology, SHA-512 cryptographic hashing, and AES encryption to provide a secure, transparent, and efficient digital marketplace for farmers and suppliers. The system was implemented using Java EE technologies with a MySQL backend and deployed as a web application accessible to three distinct user roles: Farmer, Supplier, and Administrator.

The system directly addresses the core limitations of conventional agricultural supply chains, including low security, poor traceability, dependence on intermediaries, and lack of transparency. By automatically generating an immutable six-block blockchain hash chain upon administrative approval of each transaction, the system ensures that all trade events are permanently and verifiably recorded, providing a robust audit trail that cannot be altered without detection.

Experimental testing confirmed that the blockchain hash generation module functions correctly, producing unique and tamper-evident hash chains for all approved transactions. Security testing validated the effectiveness of SQL injection defenses and session-based authentication. The system demonstrated reliable performance across all functional modules, confirming its suitability for deployment in real-world agricultural supply chain environments.

Future work will focus on integrating IoT sensors, adopting public or consortium blockchain platforms, incorporating predictive analytics for market intelligence, and developing mobile interfaces to improve accessibility for rural farming communities. This system represents a meaningful step toward a more equitable, transparent, and resilient agricultural economy.

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