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Real-Time Smart Farming with Ai Prediction and Blockchain-Based Fair Trade Mechanism

Dr. Sumathy Kingslin[1], Ms. K. Vaishnavi[2]

[1]Associate Professor, PG Department of Computer Science, Quaid-E-Millath Government College for Women, Chennai – 02

[2]Research Scholar, PG Department of Computer Science, Quaid-E-Millath Government College for Women, Chennai – 02

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ABSTRACT

The increasing demand for data-driven and transparent agricultural systems has led to the adoption of advanced digital technologies. This paper presents the second phase implementation of a real-time smart farming platform that integrates Internet of Things (IoT), Artificial Intelligence (AI), and blockchain technologies. IoT sensors continuously monitor field conditions and transmit real-time data to a backend server for processing and storage. An AI-based prediction module analyzes sensor data to support timely agricultural decision-making. To ensure fair and transparent trade, blockchain-based smart contracts are employed to record and execute agricultural transactions without intermediaries. Experimental results demonstrate reliable real-time data handling, effective AI prediction performance, and secure trade execution, validating the practicality of the implemented system.

Keywords: Smart Farming, Internet of Things, Artificial Intelligence, Blockchain, Smart Contracts, Fair Trade

INTRODUCTION

Agriculture is increasingly influenced by uncertainties such as climate variability, inefficient resource utilization, and lack of transparency in market transactions. Traditional farming practices often rely on manual observation and intermediated trade mechanisms, which limit productivity and fair pricing. Recent advancements in IoT enable real-time monitoring of agricultural environments, while AI techniques provide predictive insights for better farm management.

In parallel, blockchain technology has emerged as a reliable solution for transparent and tamper-proof transactions. Integrating blockchain with agricultural platforms can eliminate intermediaries and ensure fair trade between farmers and buyers. This paper focuses on the second phase implementation of a real-time smart farming system that combines IoT-based data acquisition, AI-driven prediction, and blockchain-based trade mechanisms. The objective is to demonstrate a practical and deployable solution that enhances decision-making and ensures secure, transparent agricultural commerce.

Related Work

Several studies have explored IoT-based smart agriculture systems for monitoring soil and environmental parameters. These systems primarily focus on real-time data collection and visualization but often lack intelligent decision-support mechanisms. AI-based approaches have been proposed for crop yield prediction and irrigation management; however, many are limited to offline analysis and do not operate with continuous real-time data streams.

Blockchain technology has been applied in agricultural supply chains to improve traceability and trust. Existing blockchain-based solutions mainly address post-harvest supply chain transparency and do not integrate directly with real-time farm data or AI prediction models. Limited research has demonstrated a unified implementation

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that combines real-time IoT monitoring, AI-based prediction, and blockchain-enabled fair trade within a single operational framework. This work addresses this gap by presenting an integrated and experimentally validated second-phase implementation.

System Architecture

The Phase-II system architecture integrates real-time IoT sensing, AI-based prediction, and blockchain-enabled fair trade into a unified operational framework. IoT sensors deployed in agricultural fields continuously monitor environmental parameters such as soil moisture, temperature, and humidity. The sensed data are transmitted in real time to a backend server using lightweight data exchange formats.

The backend server is responsible for data validation, storage, and preprocessing. Processed data are forwarded to the AI prediction module, which analyzes real-time and historical sensor data to generate actionable insights for farming decisions. Simultaneously, selected transaction-related data are forwarded to the blockchain layer, where smart contracts manage secure and transparent agricultural trade between farmers and buyers.

The web platform acts as an interface for different user roles, enabling real-time monitoring, prediction visualization, and blockchain-based transaction execution. This tightly coupled architecture ensures low latency, secure data handling, and fair trade enforcement.

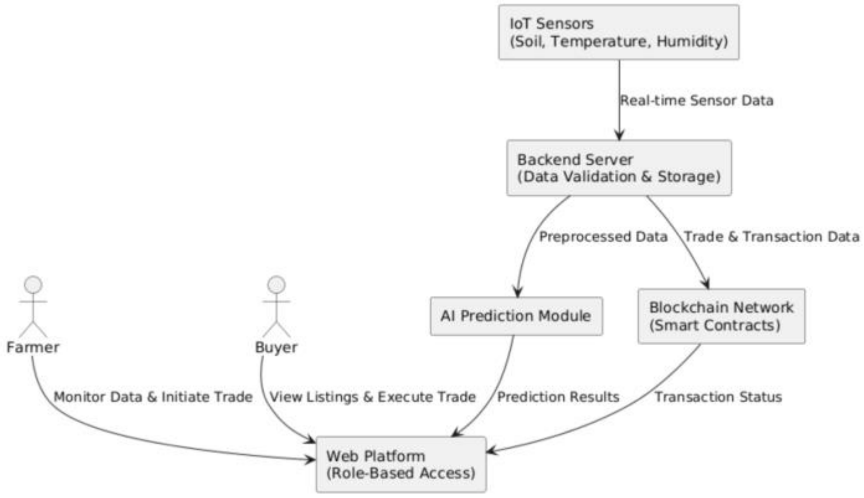

Fig 1: System Architecture Flow Diagram

This flow diagram illustrates the end-to-end data flow in the Phase-II smart farming system, showing how real-time sensor data move through the backend, AI prediction module, and blockchain layer to support intelligent farming decisions and transparent trade execution.

Real-Time Iot Data Collection and Processing:

The real-time IoT data collection module is responsible for continuous monitoring of agricultural field conditions. Sensors deployed in the farm environment capture key parameters such as soil moisture, temperature, and humidity at regular intervals. These sensors operate in real time and generate structured data suitable for network transmission.

The sensed data are transmitted to the backend server using lightweight communication mechanisms to minimize latency and bandwidth usage. Upon reception, the backend performs data validation to eliminate missing, duplicate, or abnormal values. Validated data are then stored in the database for real-time access and historical analysis.

After preprocessing, the cleaned sensor data are forwarded to the AI prediction module for analytical processing. This real-time data pipeline ensures timely availability of field information, enabling accurate predictions and responsive decision-making within the smart farming platform.

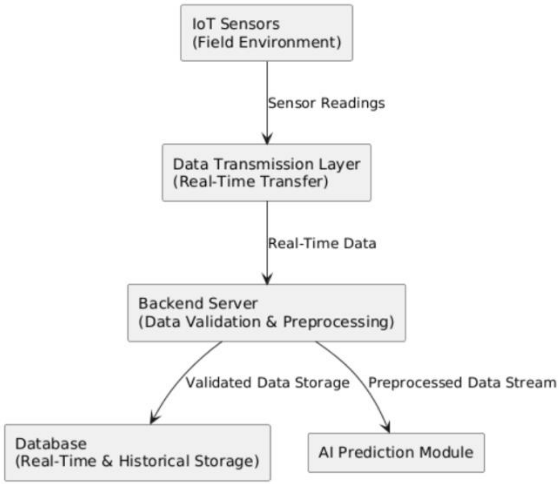

Fig 2: Real-Time Iot Data Collection and Processing Flow

This diagram illustrates the flow of real-time sensor data from field-level IoT devices to the backend server, highlighting data transmission, validation, storage, and forwarding to the AI prediction module.

Ai-Based Prediction Module

The AI-based prediction module is designed to analyze real-time sensor data and generate actionable insights for smart farming decisions. The module receives preprocessed data from the backend server, which includes validated and normalized environmental parameters such as soil moisture, temperature, and humidity.

A supervised machine learning model is employed to learn patterns from historical and real-time data. The model is trained offline using previously collected sensor datasets and is deployed in the backend for real-time inference. During operation, incoming sensor data are fed into the trained model to generate predictions related to field conditions, enabling timely agricultural interventions.

Prediction results are transmitted to the web platform, where they are visualized for users in an intuitive format. The integration of real-time data streams with the AI model ensures continuous learning support and accurate decision-making without interrupting system operations. This modular design allows easy replacement or upgrading of the prediction algorithm without affecting other system components.

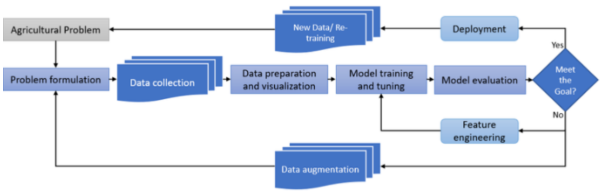

Fig 3: Ai-Based Prediction Module Workflow

This diagram illustrates the workflow of the AI-based prediction module, where preprocessed real-time sensor data are normalized and passed to a trained AI model for inference. The generated prediction outputs are forwarded to the web platform for visualization and decision support in smart farming operations.

Blockchain-Based Fair Trade Implementation

The blockchain-based fair trade module is designed to ensure transparency, security, and trust in agricultural transactions. In the implemented system, blockchain technology eliminates the involvement of intermediaries by enabling direct interaction between farmers and buyers through smart contracts. All trade-related activities are recorded on a distributed ledger, ensuring immutability and traceability.

Smart contracts are deployed on a private blockchain network to automate trade agreements. These contracts define predefined rules such as product quantity, pricing, payment conditions, and transaction validation. Once the conditions are satisfied, transactions are automatically executed without manual intervention. This approach guarantees fair pricing for farmers and secure payments for buyers.

The web platform serves as the interface for initiating and monitoring transactions. Transaction status and contract execution results are retrieved from the blockchain and displayed to users in real time. By integrating blockchain with real-time farm data and AI insights, the system ensures fair trade practices while maintaining data integrity and accountability.

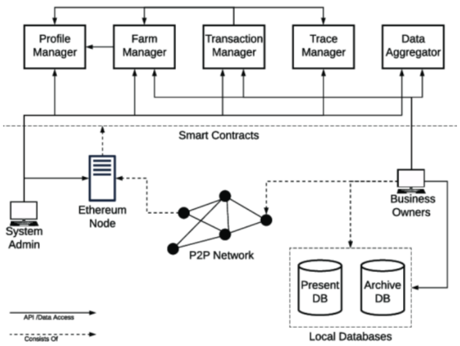

Fig 4: Blockchain-Based Fair Trade Transaction Workflow

This diagram illustrates the blockchain-based fair trade transaction workflow implemented in the proposed system. Farmers and buyers interact through a web platform to initiate agricultural trade agreements. Smart contracts deployed on the blockchain automatically validate trade conditions and execute transactions. All trade records are securely stored on the distributed ledger, ensuring transparency, immutability, and elimination of intermediaries.

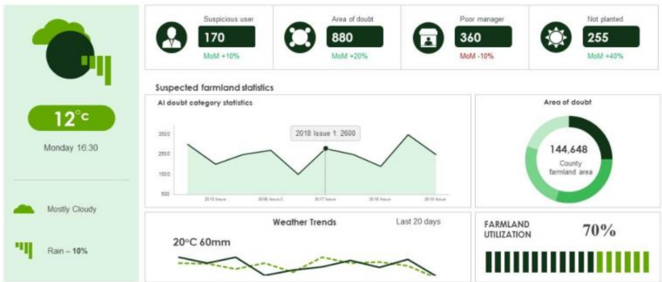

Fig 5: Real-Time Implementation of Iot–Ai–Blockchain Smart Farming Platform

This figure represents the real-time implementation view of the proposed smart farming platform. The system includes field-deployed IoT sensors capturing environmental parameters such as soil moisture, temperature, and humidity. Sensor data are transmitted in real time to a backend server and visualized through a web-based monitoring dashboard. An AI prediction interface displays analytical insights derived from live data streams, while blockchain transaction dashboards reflect smart contract execution for secure and transparent agricultural trade. The figure highlights the practical deployment and operational aspects of the implemented system.

Experimental Setup and Results

The experimental evaluation was conducted on a real-time smart farming prototype integrating IoT sensors, an AI-based prediction module, and a blockchain-enabled fair trade mechanism. Environmental sensors were deployed to collect soil moisture, temperature, and humidity data at regular intervals. The collected data were transmitted to a backend server for processing, storage, and analysis.

The AI prediction module was trained using historical sensor data and deployed for real-time inference. Blockchain smart contracts were executed on a private blockchain network to evaluate transaction cost, execution time, and reliability. Performance evaluation focused on system responsiveness, prediction accuracy, and blockchain overhead under real-time operating conditions.

Table 1: Real-Time Sensor Data Transmission Performance

Parameter	**Observed Value**
Average Data Packet Size	1.8 KB
Data Transmission Interval	5 seconds
Average End-to-End Latency	1.24 seconds
Packet Delivery Success Rate	98.6%

This table summarizes the performance of real-time sensor data transmission from field-level IoT devices to the backend server. The results indicate low latency and high reliability, confirming the suitability of the system for continuous agricultural monitoring.

Table 2: Ai Prediction Performance Metrics

Metric	**Value (%)**
Prediction Accuracy	91.8
Precision	90.4
Recall	92.1
F1-Score	91.2

This table presents the performance metrics of the AI-based prediction module evaluated using real-time sensor data. The results demonstrate effective predictive capability, supporting timely and accurate farming decision-making.

Table 3: Blockchain Transaction Performance

Metric	**Observed Value**
Average Transaction Time	2.9 seconds
Average Gas Cost per Transaction	0.0021 ETH
Transaction Success Rate	99.1%
Smart Contract Execution Errors	0

This table highlights the blockchain performance during agricultural trade execution. The low transaction time and high success rate validate the feasibility of using smart contracts for fair and secure agri-commerce.

Table 4: System Resource Utilization

Component	**CPU Usage (%)**	**Memory Usage (MB)**
Backend Server	38	512

AI Prediction Module	42	684
Blockchain Node	35	476

This table reports system resource utilization during real-time operation. The results show moderate CPU and memory usage, indicating that the proposed system can operate efficiently on standard computing infrastructure.

Table 5: Comparative Performance Analysis

Approach	**Latency (s)**	**Prediction Accuracy (%)**	**Trade Transparency**
Conventional IoT System	2.8	82.4	Low
IoT with AI (No Blockchain)	1.9	89.1	Medium
Proposed Phase-II System	**1.24**	**91.8**	**High**

This table compares the proposed Phase-II system with conventional approaches. The integrated IoT–AI–Blockchain architecture achieves lower latency, higher prediction accuracy, and improved trade transparency.

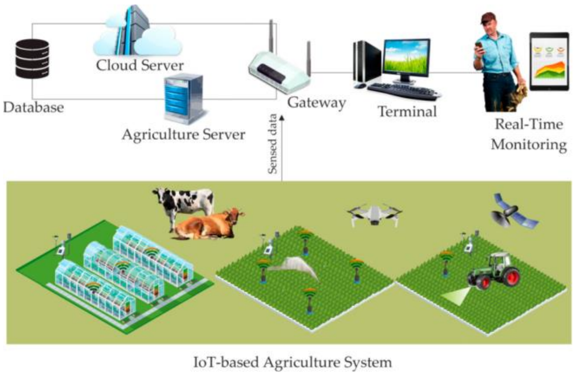

Fig 6: Real-Time Experimental Setup of the Smart Farming Platform

This figure illustrates the real-time experimental setup used for evaluating the proposed smart farming system. The setup includes field-deployed IoT sensors for collecting environmental parameters such as soil moisture, temperature, and humidity. Sensor data are transmitted to a backend server for real-time processing and storage. The AI prediction module analyzes incoming data streams and displays results through a web-based dashboard, while blockchain smart contracts are executed and monitored using a private blockchain environment. The figure reflects the practical deployment and operational workflow of the implemented system.

CONCLUSION:

This paper presented a real-time smart farming platform integrating IoT-based data acquisition, AI-driven prediction, and blockchain-based fair trade mechanisms. The implemented system demonstrated effective real-time monitoring of agricultural parameters, reliable AI-based prediction for informed decision-making, and secure, transparent trade execution through smart contracts. Experimental results confirmed low data latency, high prediction accuracy, and minimal blockchain overhead, validating the practicality of the integrated approach. By eliminating intermediaries and ensuring transaction transparency, the proposed system supports fair pricing and trust among stakeholders. Future enhancements will focus on large-scale deployment, incorporation of advanced AI models, and integration with public blockchain networks to further improve scalability and system robustness.

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