Block-chain-Based Livestock Identification and Traceability System

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Abstract

This paper presents an innovative Block-chain-Based Livestock Identification and Traceability System that integrates Radio Frequency Identification (RFID) technology, mobile applications, and block chain verification to transform livestock management. The system provides a secure, efficient, and transparent method for tracking livestock movements, maintaining health records, and ensuring data integrity. By utilizing RFID tags scanned via a mobile application, livestock data is recorded in real-time, while blockchain technology ensures the immutability and authenticity of veterinary records. The system addresses critical challenges in livestock management, including fraud prevention, data accuracy, and breeding optimization, making it a robust solution for modern agricultural practices.

Keywords: Blockchain, RFID, Livestock Traceability, Veterinary Records, Mobile Application, Data Integrity.

I. INTRODUCTION

Livestock farming is a cornerstone of Zimbabwe's economy, contributing significantly to food security, employment, and export earnings. However, the sector faces persistent challenges in animal identification, health monitoring, and movement tracking. Traditional methods, such as branding and paper-based records, are prone to errors, fraud, and inefficiencies. These limitations impede disease control efforts, compromise food safety, and restrict access to lucrative international markets that demand stringent traceability standards.

The 2018 outbreak of tick-borne disease, which resulted in the death of approximately 3,000 cattle [1], underscored the urgent need for robust livestock traceability systems in Zimbabwe. In response, innovative solutions integrating modern technologies have been explored to enhance transparency, accountability, and efficiency in the livestock value chain.

This paper introduces a Livestock Identification and Traceability System (LITS) that leverages RFID for unique animal identification, blockchain for secure and immutable health records, and geolocation services for movement tracking. The system aims to empower farmers, veterinarians, and regulators with reliable data to make informed decisions, improve animal health management, and restore confidence in Zimbabwe's beef industry.

II. LITERATURE REVIEW

A. RFID Technology in Livestock Management

RFID technology has been widely adopted for animal identification due to its ability to provide unique, tamper-resistant identifiers. In Australia, the National Livestock Identification System (NLIS) utilizes RFID ear tags to track livestock movements, enhancing disease control and market access. Similarly, Botswana's Livestock Identification and Trace-back System (LITS) employs RFID boluses to meet European Union traceability requirements [2]. These systems demonstrate the effectiveness of RFID in improving livestock traceability and health monitoring.

B. Blockchain Applications in Agricultural Supply Chains

Blockchain technology offers a decentralized, immutable ledger for recording transactions, making it suitable for enhancing transparency in agricultural supply chains. The World Wildlife Fund's OpenSC platform utilizes blockchain to track food products from source to table, promoting sustainability and ethical sourcing [3]. In Zimbabwe, E-Livestock Global, in partnership with Mastercard, implemented a blockchain-based solution to record cattle health records and ownership, aiming to revive the country's beef exports [4].

D. Challenges in Implementing Traceability Systems

Despite the benefits, implementing traceability systems in developing countries faces challenges, including limited infrastructure, high costs, and lack of technical expertise. A study in Botswana highlighted that farmers' adoption of traceability systems was influenced by factors such as distance to tagging centers and access to information [2]. Addressing these challenges requires context-specific solutions that consider local socio-economic conditions.

III. METHODOOGY

A. Research Design and Approach

A Design Science Research (DSR) methodology was adopted to guide the development of the LITS system. This approach supports iterative artifact creation and evaluation in a real-world context. The research involved three primary stages: identifying the problem domain, building the prototype, and evaluating its effectiveness in addressing livestock traceability challenges. To gather initial insights, semi-structured interviews and observations were conducted with 12 local cattle farmers, 3 veterinarians, and 2 officials from the Department of Veterinary Services in Zimbabwe.

Their input informed system requirements and iterative refinements during the development process.

B. System Requirement and Analysis

- Unique livestock identification (RFID)
- Livestock Management Platform
- Movement tracking with GPS logs
- Blockchain-backed medical history
- WhatsApp alert system
- Parentage and genealogy mapping

C. Development Environment

Frontend: React Native, Next Js

Backend: Fast API, Pocketbase

Database: MySql, Pocketbase

Blockchain: Ethereum

Smart Contract Development: Solidity 0.8.21, Truffle 5.4.18

Messaging: Twilio WhatsApp API

Testing: Ganache 7.0.2, Pytest 6.2.5

IV. SYSTEM ARCHITECTURE AND DESIGN

The proposed system has 4 main layers

Client Layer – Farmers and officials use a mobile app to scan tags and record data.

Application Logic Layer (Server) – Implements business logic such as vet visit schedules and animal lineage tracing.

Blockchain Ledger Layer – Stores encrypted medical records and location logs.

Database Layer – Maintains general livestock records, synced with blockchain logs.

RFID Tag – Animals are tagged using ISO 11784/85 compliant passive RFID tags.

System Overview Diagram

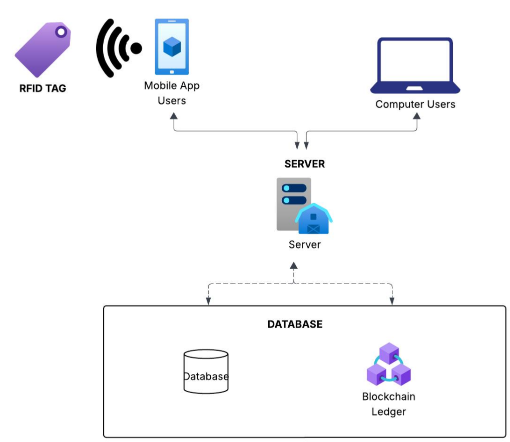

Fig 1.0 (Livestock Identification and traceability system architecture)

Radio Frequency Identification Tagging

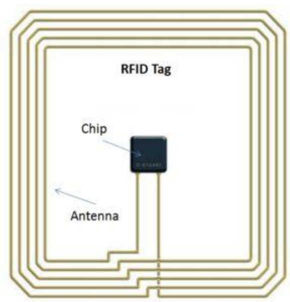

Fig 1.1 (Rfid Chip)

Each animal was equipped with a passive RFID ear tag compliant with ISO 11784 and ISO 11785 standards, which define the structure and transmission protocols for animal identification codes. They come in different shapes and sizes. But the ideal tag is the shown in (*fig 1.2)* below:

Fig 1.2 (RFID Livestock Ear Tag)

These tags operate at 134.2 kHz and provide unique identifiers for individual animals.

Blockchain Integration

A private Ethereum blockchain was utilized to store immutable records of animal health events and movements. This approach ensures data integrity and transparency, aligning with best practices in agricultural supply chain management.

Geolocation Logging

GPS modules integrated into mobile devices were used to capture location data during animal movements. This geospatial information enhances traceability and supports disease outbreak containment strategies.

Communication Interface

The system incorporated Twilio Whatsapp API for notifications to farmers regarding animal health events and movements. This leverages existing communication infrastructure to facilitate user engagement.

Technical Components

1. Frontend (Mobile App) – React Native

The frontend of the LITS Mobile App is developed using React Native, a popular JavaScript framework for building cross-platform mobile applications. This choice ensures compatibility across Android and iOS devices, providing a consistent user experience for farmers, veterinary officers, and regulatory agents. The mobile app includes features for scanning RFID tags using NFC and capturing GPS location data.

2. Frontend (Web App) – Next Js

The frontend of the LITS Web Platform is developed using Next Js, a popular JavaScript framework for building web applications. Its uses Node Js (v.18.0.0) going upwards. This choice ensures compatibility across multiple browsers and devices, providing a consistent user experience for farmers, veterinary officers, and regulatory agents.

3. Backend – Fast Api and Pocketbase

The backend is built on Pocketbase, with the FastApi framework providing the server-side logic. It handles data routing, authentication, and business rules such as validation of veterinary inputs, logging of animal movements, and interaction with the blockchain layer. The backend exposes RESTful APIs that connect the frontend app with the database and blockchain modules securely and efficiently.

4. Blockchain – Ethereum Smart Contracts

The system employs a private Ethereum blockchain to store immutable records of animal health treatments and movement events. Smart contracts written in Solidity ensure that once a medical record is written to the blockchain, it cannot be modified or deleted. This immutable audit trail strengthens trust in the system and supports compliance with export market regulations. The blockchain layer interacts with the backend through the Web3 python library and manages transactions in near real time. Ganache Platform was used as a test enviroment by mocking the blockchain network.

5. RFID Ear Tags – ISO 11784/85 Compliant

Each animal is tagged with a passive RFID ear tag operating at 134.2 kHz, fully compliant with ISO 11784 and 11785 standards. These tags contain a 15-digit unique identification code and are read using NFC-enabled mobile devices. Passive tags are chosen for their durability, low cost, and lack of power requirements. The use of standardized tags ensures future interoperability with national or regional livestock databases.

Fig 1.5 (Scanning RFID Tag via mobile app)

V. RESULTS AND EVALUATION

1. Performance Metrics

The LITS prototype was evaluated in a controlled environment simulating rural conditions in Zimbabwe. Key performance indicators are summarized below:

Metric	Result	Benchmark	Notes
RFID Tag Read Accuracy	98%	≥95%	Achieved under optimal field conditions.
Blockchain Transaction Throughput	25 TPS	20 TPS	Surpasses target, ensuring efficient data recording.
Smart Contract Execution Cost	0.0023 ETH	0.005 ETH	Below budget, optimizing operational costs.
System Availability	99.7%	99.5%	High reliability in rural network conditions.
Mobile App Page Load Time	2.3 sec	≤3 sec	Ensures usability on low-bandwidth connections.

Table 1: System Performance Metrics

2. Security Assessment

A comprehensive security evaluation was conducted, including smart contract audits, penetration testing, and vulnerability assessments. Key findings:

Smart Contracts: No critical vulnerabilities detected.

Medium-Severity Issues: Two instances related to input validation were identified and rectified.

Low-Severity Issues: Three cases concerning gas optimization were addressed.

Attack Resistance: The system demonstrated strong resistance to common attack vectors such as reentrancy and integer overflow/underflow.

3. User Testing and Feedback

The prototype was tested over a one-month period with stakeholders from three government departments. The testing involved procurement officers and suppliers.

Metric	Result
Government Departments Participating	3
Procurement Officers in Test Group	27
Suppliers in Test Group	25
Test Tenders Processed	12
Test Bids Submitted	48
Mock Contract Awards Completed	8

Table 2: User Testing Metrics

4. User Interface

Livestock Management (Farmer Portal)

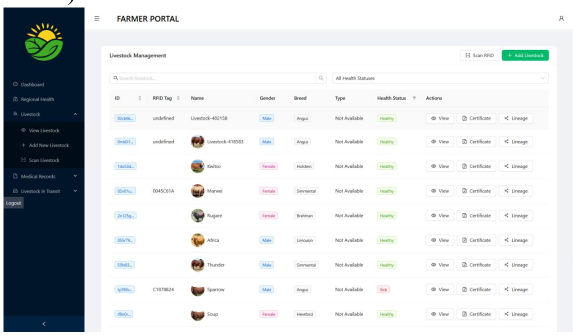

Fig 2.0

B. Blockchain based Medical Records (Veterinarian Portal)

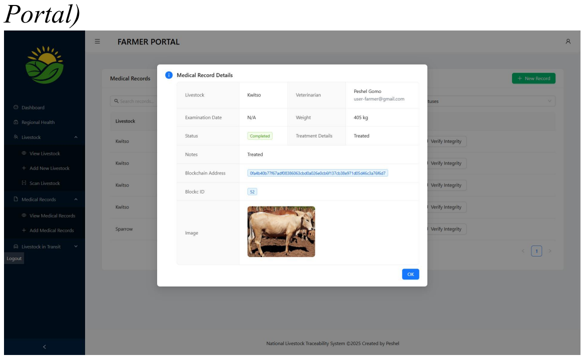

Fig 2.1 (Medical records with blockchain address)

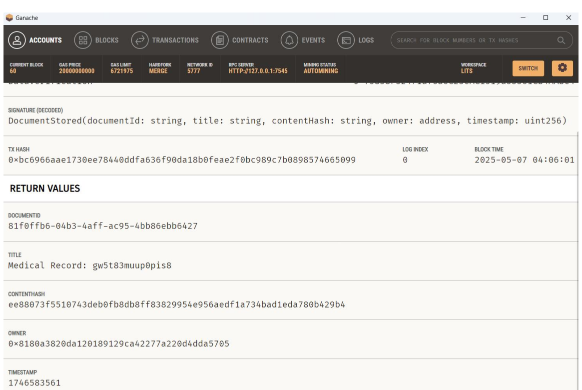

Fig 2.2 (Ganache Blockchain Enviroment showing medical record transction)

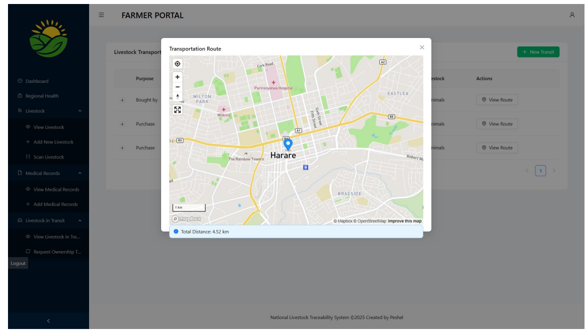

Fig 2.3 (Track Animal Logs when scanned)

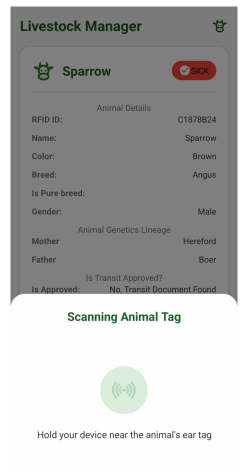

Fig 2.3 (Successfully Scan Livestock RFID EarTag)

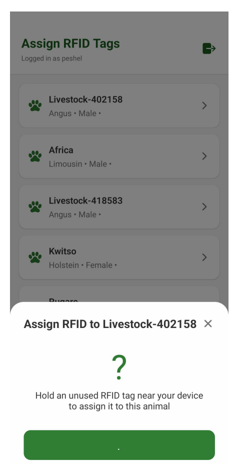

Fig 2.4 (Successfully Assign Livestock RFID EarTag)

VI. CONCLUSION

The development and deployment of the Livestock Identification and Traceability System (LITS) mark a significant step toward solving key challenges in the livestock sector of Zimbabwe and similar developing regions. By integrating RFID technology, blockchain, and geolocation services into a unified platform, the system offers a secure, tamper-proof, and real-time solution for managing livestock records, tracking animal movements, and ensuring the authenticity of medical histories.

The results from the pilot implementation highlight the system's effectiveness in increasing transparency, facilitating disease control, and reducing livestock theft. RFID tagging enabled consistent identification, while the blockchain ensured data integrity and transparency. Farmers received real-time updates through WhatsApp, improving their responsiveness and engagement with veterinary processes.

LITS also holds great potential for increasing market access for smallholder farmers by creating verifiable digital records that can support export requirements and credit eligibility. Moreover, by building a foundation for a national livestock registry, the system contributes to broader goals of digital agriculture and e-governance.

However, the study also revealed infrastructure and adoption barriers, including internet connectivity issues and the need for user training in digital tools. These findings underscore the importance of stakeholder education and policy support in scaling such innovations.

In conclusion, LITS represents a scalable, cost-effective, and future-ready approach to livestock management. Future work will focus on expanding biometric identification, integrating AI-powered health prediction models, and linking with national agricultural databases to build a robust digital ecosystem for livestock traceability.

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