FarmIns: Blockchain Leveraged Secure and Reliable Crop Insurance Management System

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Abstract. Farmer uses traditional crop insurance to protect their farms against crop loss and natural risks. However, farmers are concerned about crop insurance claims due to delays in processing claims that cost significantly. Insurance fraud is another problem in crop insurance which costs significantly for insurance companies. The proposed FarmIns framework uses blockchain technology, allowing farmers to create and manage insurance agreements with insurance providers through smart contracts and creating a verifiable log of farm monitoring parameters to help insurance providers verify and approve claims promptly. FarmIns uses the Internet of Agro-Things (IoAT), and video surveillance technologies like Closed-Circuit Television (CCTV) to monitor and provide reliable farm data to process claims. FarmIns also acts as Decision Support Tool (DST) for both the insurer and the insured.

Keywords: Agriculture Cyber-Physical System (H-CPS) · Internet-of-Agro-Things (IoAT) · Blockchain · Smart Contract · Insurance Claim.

1 Introduction

Agriculture is one of the important occupation for sustainable living and providing food safety for rapidly increasing population. With raise in population and increase in food demand, traditional farm techniques has been modernized by adapting latest technological advancements to make the farms more productive and use less resources [?,?].

Traditional insurance has several issues, such as fraudulent claims and the lack of transparency and complexity of the review process, which will take significant time and could negatively impact farmers. Therefore, the proposed framework, FarmIns, which is based on weather-based index insurance (WBII), addresses these issues, and solves them with the help of blockchain technology, smart contracts, cloud computing, a decentralized oracle network, and the Internet of Agro-Things (IoAT). Smart contracts are used for creating and managing insurance policies between farmers and insurance companies along with providing a robust Role Based Access Control mechanism (RBAC). Cloud computing is used to create a decision support tool for the efficient management of the farm. Decentralized oracles are used to provide reliable data to the smart contracts for efficient verification of real-time farm parameters to process claims.

2 Related Prior Works

Different blockchain based solutions for farm insurance has been explored in this section. Neo drought has proposed NEO smart contract based irrigation monitoring system [?]. The proposed framework in [?], focusing on the gas fees optimization while relying on single API to make a decision. [?] presents a blockchain based crop insurance with smart contract that makes an agreement between the farmers and insurance company. At [?] uses blockchain Hyperledger Fabric for preventing false claim. At [?] the proposed system address several issues the farmer is facing such as middle man and transparency. [?] uses Proof of Authority (PoA) consensus algorithm to proof of capability of blockchain to be used in insurance sector as for different cases such as supply-chain and car insurance. At [?] proposed framework uses private blockchain network (Hyperledger Fabric) for insurance services with smart contract to automate insurance services in secure manner such as claim automation to reduce the claim process.

The proposed framework FarmIns has a different framework and design, as well as additional functionalities, to streamline the process between the insurer and the insured with security perspectives. It enables IoAT to monitor the farm and cloud to process and authenticate IoAT devices. FarmIns uses blockchain technology and smart contract to securely stores the data and automates the claim process and other insurance procedures. It also provides risk elimination with the aid of a notification system to minimize loss to the greatest extent possible. In addition, Chainlink is used to validate the data, provide an accurate value, and avoid reliance on a single data provider. At table 1 presents the comprasion of proposed system and other related works.

3 Novel Contributions of The Current Paper

3.1 The Problem Addressed

Traditional crop insurance has multiple of drawbacks which have a significant impact on the farmer, especially smallholder farmers.

Due to distributed nature of entities participating in the insurance management system creates lack of transparency and in turn causes processing delays. Most of today's systems are centralized which are prone to security threats and data manipulations. Hence, getting reliable data for insurance companies to process the claims is a problem. Along with these, false claims are another problem faced by insurance providers which could cost a lot. Deployment of IoAT devices can help in monitoring real-time data but lack of device security at IoAT devices also needs to be addressed.

Table 1: IoT and Access Management Related Work

Framework	**IoT Integration**	**Access-Control Management**	**Real-Time DST**	**IoT Data Validation**	**IoT Data Realiability And Accuracy**
Nguyen et al, 2019 [?]	No	No	Yes	NA	NA
Salem et al, 2021 [?]	No	No	Yes	No	Low
Jha et al, 2021 [?]	No	Yes	No	No	No
Gera et al, 2020 [?]	No	No	No	No	No
Patel and Shrimali, 2021 [?]	Yes	Assumption	No	No	No
Aleksieva et al, 2020 [?]	No	No	No	No	No
Khan et al, 2021 [?]	Yes	Yes	No	No	No
FarmIns	Yes	Yes	Yes	Yes	High

3.2 The Solution Proposed

The proposed solution transitions from centralized to decentralized systems in order to increase transparency and integrity, avoid single points of failure, enhance security and reliability, avoid third parties in an untrusted environment, and secure the automation insurance process. In addition, rather than relying on a single data provider or API service, the farmland is monitored by multiple data providers with value aggregation to ensure accuracy and avoid fake data and single points of failure.

3.3 The Novelty of The Proposed Solution

Proposed FarmIns automates the process of managing crop insurance by leveraging hybrid smart contracts. These hybrid smart contracts consume data from multiple data providers along with weather APIs to provide reliable farm monitoring data to the insurance companies which not only avoids the false claims but also aid in faster processing times. Proposed FarmIns also uses IPFS integrated to blockchain which will reduce the cost of managing large information off-chain instead of expensive on-chain storage. It also makes use of cloud functionalities to act as a Decision Support Tool (DST) for farmers to take prompt actions.

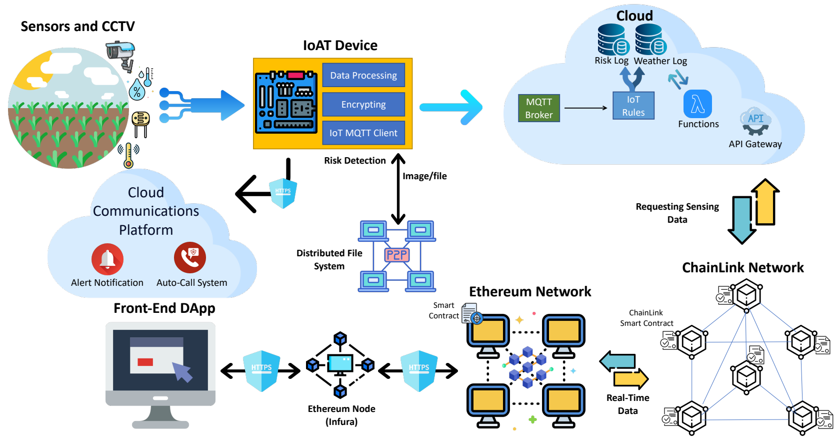

Fig. 1: FarmIns Architecture.

4 FarmIns Architecture

FarmIn's framework is comprised of various technologies that collaborate to provide a reliable and scalable system. IoAT devices are used to sense environmental parameters and create a real-time monitoring system. These steps are shown in Figure 1. IoAT devices creates a secure channel to cloud using key and certificate authority (CA) files. Data from sensors will be relayed to cloud by using lightweight Message Queuing Telemetry Transport (MQTT) protocol. Sensory data received in cloud is processed based on predefined set of rules to check for abnormalities. These abnormalities will trigger a simple notification for farmers to take prompt actions and mitigate crop losses. In case of abnormal values, IoAT device also takes pictures of surroundings and will be uploaded to the distributed file system Inter Planetary File System (IPFS). Cloud component designed in the proposed architecture also makes the sensory data available to decentralized oracles by using Application Programming Interface (API) gateway. Multiple such data providers will provide data to oracle which will aggregate and provide reliable data to smart contracts to automate the process of managing insurance policies.

4.1 Stakeholders

FarmIns has four primary stakeholders: farmer, approved insurance provider (AIP), government agency like Federal Crop Insurance Corporation (FCIC) and the data provider (DP). Approved insurance provider offers crop protection against serves weather and disaster while FCIC shares the risk estimate with AIP and provide subsidy to a farmer to encourage the farmer to insure the farmland. Data providers are utilized to provide accurate weather data to FCIC and AIP for better risk estimate and aid in processing of claims.

Algorithm 1 Sensing Environmental Variables and Sending It to Cloud

Require: Certificates and keys for IoAT thing, Environmental Parameters.
Ensure: Stored in cloud or Discarded.

Sensing node reads and loads and key pairs and Certificates
Create a secure MQTT communication channel to cloud
while (MQTT.status() == connected) **do**
  conn ← MQTT.connect(CA$_{cert}$,PrK,PuK)
end while
for Every 30 seconds **do**
  Environmental Parameters (params) ← sensors.read() and converted to a JSON
  JSONString ← JSON.dumps(params)
  Sensing node creates a message (MSG) with all the metadata like Sensing node device ID
  MSG ← JSONSTring.append(headers)
  IoAT device sends the data to the cloud using MQTT connection.
  conn.publish(MSG,TopicName)
end for
Cloud Authenticate the IoAT device with PKI and CA
if IoAT Authenticated **then**
  Store the data to the proper action/log DB and with timestamp
else
  Discard
end if

4.2 The Proposed Algorithms For FarmIns

As presented in Algorithm 1, each IoAT device connected with different sensors such as GPS Module, water level detection and temperature sensors. The environmental parameters collected are first converted into JSON format before sending it to the cloud component which acts as data provider for the distributed data source. Each IoAT device has their own keys and certificates to create a secure communication channel to the cloud using lightweight communication protocol.

Algorithm 2 explains the process of getting data from the cloud until stored to the blockchain.

5 Implementation And Validation

5.1 Implementation

FarmIns implementation consists of hardware and software tools. The hardware tools are raspberry Pi 4 Model B as IoAT device and used sensors to measure the environmental variables as presented at Figure 2 . The software parts are solidity programming language to write hybrid smart contracts and react.js and web3.js for building web interface and smart contract interaction as end-user application. Cloud component is designed to act as data provider network for distributed data source Oracle.

Algorithm 2 From Cloud to stored on Blockchain

Require: Weather Data and data from sensing node.
Ensure: A transaction hash with an immutable log generated in blockchain ledger.

```
Insurance provides calls the data smart contract to fetch environmental data
for Each call do
    dataSmartContract.fetchWeatherParams() only InsuranceProvider()
    for Each Data Provider do
        fetchWeatherParams function creates a chainlink request with given Oracle
        Job ID (JID)
        request (req) ← buildChainlinkRequest(JID, msg.sender,fulfill function)
        API url is updated to the request
        req ← req.add(url)
        Path to the data in the response is added to the request
        req ← req.addPath(Path of weather data in JSON response)
        Chainlink request is sent to fetch data
        Obtain the weather data through API gateway
        weatherData ← sendChainlinkRequest(req)
    end for
    Obtained the accurate values through Oracle aggregator contract
    Smart Contract generates an event with the weather data and store the data
end for
```

Table 2: Load Test Results

Test Number	Number of Messages	Elapsed Time (seconds)	Messages per Second
1	400	0.03192	12541.56
2	600	0.04258	14089.87
3	1200	0.09153	13109.55
4	1600	0.18477	8659.97

5.2 FarmIns Validation

5.3 Cost Analysis And Time Analysis

The cost analysis is divided into two major parts: deployment cost analysis for smart contracts and functional cost analysis. The average cost of smart contract deployment is 0.005787 ETH. While the average functional cost analysis is 0.0007724 ETH, each data fetch from decentralized data source costs 0.1 LINK tokens. All these costs can be avoided by using private networks. Figure 3 presents the time consumed from sensing operation till the environmental data stored on cloud which acts as data provider. Table 2 , it demonstrates the system's performance and responsiveness with respect to different loads.

5.4 Security Analysis

The proposed FarmIns architecture ensure data integrity and device authentication for IoAT devices using public key infrastructure (PKI). This prevents the

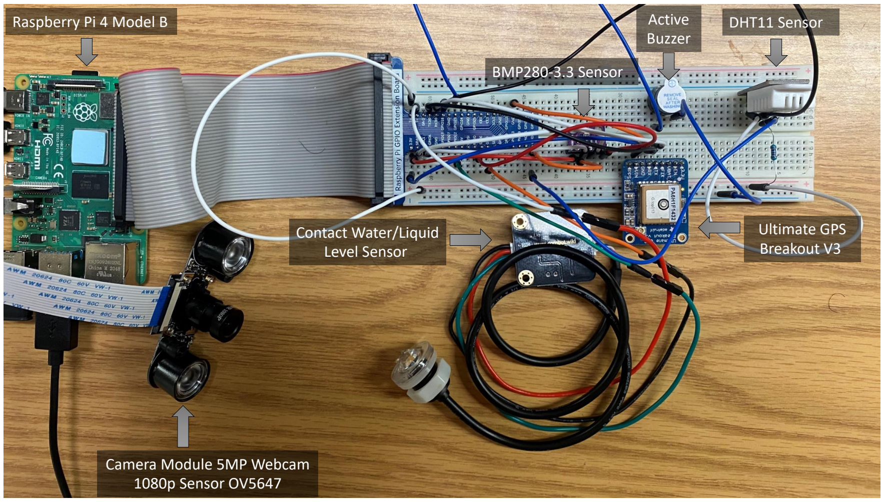

Fig. 2: Hardware Implementation.

false weather or environmental parameters entered into the system. Role Based Access Control (RBAC) mechanism is implemented in proposed FarmIns to ensure different entities participating in the network will have their own functions which cannot be accessed by other entities with different roles. Transparent and single source of truth ledger is provided by utilizing blockchain which ensures the auditability of the proposed system. Along with all these, implementing oracle which integrates the data from multiple data providers and provide reliable data to the smart contracts ensures the data security.

6 Conclusion

Proposed FarmIns system avoids many problems with traditional crop insurance systems such as faster processing of insurance claims by automating the procedures using smart contracts. Blockchain usage provides single source of truth which transparent across all the distributed entities in the system, which increases trust in the network. FarmIns also makes use of environmental parameters of the farm collected using IoAT which will give a better damage estimate in case of claims. Cloud functions are also implemented which act as DST for farmers that assist in taking prompt actions and avoid any extensive crop damages. Implementing hybrid smart contracts combined with Oracle ensure, data fed into the blockchain network is reliable.

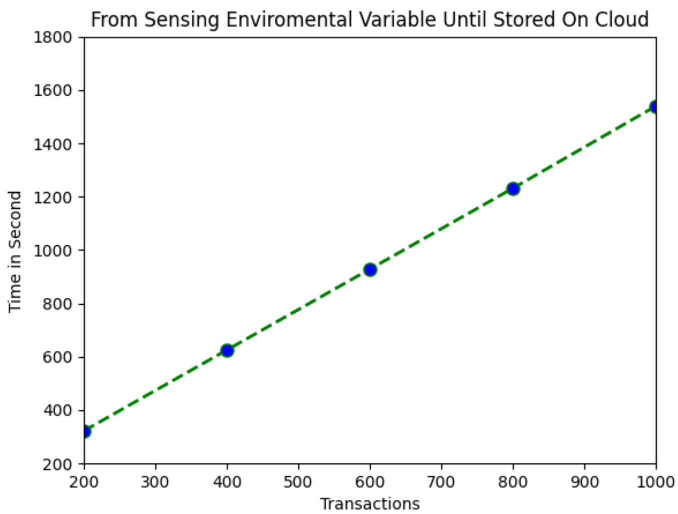

Fig. 3: Time Analysis.