Blockchain Based Supply Chain for Agriculture

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***Abstract*—The burning questions which have struck the farm supply chains are data manipulation, inability to possess transparency and inability to guarantee the authenticity of the products between the farm and the customer. It is likely that the traditional centralized systems are traceable, the stakeholders in the system will experience mistrust and problems with the data alteration. In order to eliminate these challenges, this project will suggest an agricultural trace system that is built on blockchain technology that will ensure safety, transparency, and inexpressibility of the data processing. The farmers, the distributors, retailers and consumers can access the system in a web based interface that enables them to access and verify the agricultural batch information in all the levels of the supply chains. The entire history of the products is made available through the assistance of the QR codes. Smart contracts also make the storage of cryptographic hah values more efficient and less storage overhead is incurred because the storage is stored in the blockchain. The off-chain data is operated through the assistance of a cloud database, to become more scalable. The given system will simplify the processes and time to check them compared to the current centralized methods and enhance the degree of trust, the data integrity, and traceability. The given solution challenges the realisticness and effectiveness of the introduction of the blockchain technology as the instrument of the supply chain of the agricultural products functioning in the secure environment.**

***Index Terms*—Blockchain, Agricultural Supply Chain, Smart Contracts, Proof of Authority, SHA-256 Hashing, QR Code Verification, Data Integrity, Decentralized Systems.**

I. INTRODUCTION

Agricultural supply chain has become a significant part of the global food system that may have a direct impact on consumer confidence, food quality and safety. The traditional forms of agricultural supply chain management systems are however always most commonly founded on manual record keeping and central database that have the drawbacks of data manipulations, lack of transparency and inability to offer effective traceability processes[1]. These problems complicate the problems of the customers to find the origin of the product, how it is grown and the circumstances under which the product is processed along the chain of supply.

This is where the blockchain technology has come in as one of the possible solutions to these challenges in the recent years bearing in mind the decentralized, immutable and transparent characteristic of the technology[2]. Blockchain is a disseminated ledger technology that puts information that is disseminated among several nodes and is not able to be altered without the approval of the system. This factor makes blockchain especially well-scaled to optimize the farm item traceability supply chain in which the ability to determine the product to the consumer since the farm end would be essential[3].

It uses smart contracts as blockchain architecture to automatize safe mechanisms of supply chain. Smart contracts are software programmed and are designed to be self executable and may also be a self verifying program, which does not need the service of a middle man and may use set rules[4] in giving validations through Proof of Authority consensus mechanisms, consisting of known and trusted validators. The other appropriate alternative is PoA to allow permissioned agricultural networks[5] since PoA is cheaper to compute than the conventional methods in consensus as well as it can support transaction in a smaller time than the conventional methods.

The data integrity requirement is the other requirement of supply chain system. The SHA-256 hashing algorithm is applied to transform agricultural data to cryptography hash values of a constant length and apply them to detect any form of tampering of stored data or determine the authenticity of stored data stored

safely[6]. Additionally, authentication of QR codes will also help in the transparency and trustworthiness of the system because a customer can be provided with history of the product and verify it after scanning it once[7].

The given decentralized system will improve effectiveness, privacy and transparency of the agricultural chain of supply administration since it will optimize blockchain technology, PoA consensus, SHA-256 hash and access to access QR code. This system will enable in saving a good portion of the food fraud, enhancing food traceability and consumer confidence in this system a great improvement over the traditional centralized system[8].

II. EXISTING SYSTEM

The foundation of most of them is that most of the stakeholders like farmers, distributors, processors, and retailers respectively store all product information in the centralized architectures and manual record keeping systems on most cases of the agricultural supply chain management system[1]. Since these systems require the trust of third parties to store and manipulate the data, it lacks transparency and thus the dependance on centralized authorities. This is one of the primary disadvantages of the current system since it can be easily accessed and changed by hackers. It has a point of failure since the information is stored in centralized database, and this exposes the system to outage, data breach, and cyber attacks [2]. Moreover, the process of data entry by human operators causes human errors, delays in updating records, and delays between supply chain processes.

Also, the absence of end-to end traceability prevents the customers and regulatory agencies to verify important product information such as origin, growing methods, handling conditions and transportation history of the product[3]. Food fraud products have greater chances of happening in case there is no direct and unbreachable verification system. Since the visibility cannot be seen in real time, product identification and recall processes are tedious and useless in cases of food contamination or quality issues. With everything taken into consideration, the current agricultural supply chain systems do not guarantee data integrity, transparency, and stakeholders trust. These are the disadvantages that would underscore the need to have a decentralized, safe, and effective traceability system in order to increase customer confidence, accountability and food safety.

Due to its high use of IoT sensors, the traditional system is more costly in general and has more advanced maintenance. Real-time sensor data broadcasting requires ambient internet access and is therefore not easy to roll out in rural and remote agricultural regions. Wrong or invalid data can be put in system due to wrong reading or sensor faults. The deployment and operating cost is also a deterrent to adoption especially in small-scale farms. In addition, there might be security and privacy concerns, which can be caused by central processing of sensor-derived data. Due to the low level of consumer interaction, end users cannot determine the authenticity of the product by themselves. The scalability problems associated with the system affect performance and long-term sustainability because they occur with the increase in the number of sensors and the volume of the generated data.

III. PROPOSED SYSTEM

The blockchain-based agricultural supply chain traceability platform that is presented by the proposed system is expected to guarantee transparency and accuracy in the process of the information transfer, as well as, the safety of the information between all the stakeholders within the agricultural ecosystem. The system is written in the form of web based decentralized application that follows next in a bid to circumvent the shortcomings of the traditional centralized traces systems by incorporating both blockchain and cloud services. The firebase authentication is used to implement user authentication and identify management to ensure safe, scalable and reliable access control. Access control is done on job basics so that each participant can have the authority to make sure that only what he or she is offered to perform is done regarding his/her job as well as email-based access is provided in order to make sure that all the stakeholders like farmers, distributors, and retailers are also verified. Firebase improve system security since the system will not require management of human passwords.

A Supabase cloud database holds all the supply chain information, including the generation of batches, transportation, geolocation information, and retail information. Supabase has organized SQL-based data storage system helping in read fast and efficient data retrieval and is particularly useful in consumer-side authentication. To ensure consistency and reliability of data and connection of the data, each user who has made an authenticated request with firebase will be mapped to the Supabase database with a firebase UID. According to the Infura API service, the offered system will incorporate Ethereum blockchain as a component of flawlessness and impossibility to abuse. The sepolia test network is a smart contact that makes use of a Proof of Authority consensus mechanism in order to provide quick and inexpensive transaction validation. Each event in the supply chain is hashed using the cryptography algorithm of the hashing hash SHA-256 rather than storing all the data in the blockchain hence the information is checked by the system hence data integrity, anonymity is ensured and cost is minimized.

Farmer level Batch ID is given to each and every batch of agricultural products and it is coded in the same single QR, a digital identifiable of the product and it is identical across the supply chain. Upon scanning the QR code by the distributors or retailers, real-time information such as timestamp and geolocation is recorded and hashed and sent to the blockchain with the full data in the Supabase database following the append-only model. The consumer module that has login-free verification feature enables the end user to monitor the life cycle of the products through the QR code in the farm to the retailing process. To ensure that there was validity in the information, the system re-computed the hash of the database records that were read and compared it with the blockchain hash. Any difference between the computed and recorded values of the hash is quickly demonstrated to represent the manipulation of data.

Altogether, the suggested system is a successful merge of Firebase authentication, Supabase cloud storage, Infuraenbled blockchain, and associated with traceability to provide a transparent, safe, scalable, and cost-effective solution to the agricultural supply chain offered in academic publications, as well as in the real world.

IV. METHODOLOGY

The hybrid on-chain-off-chain design will also be decided on the proposed design so that agriculture supply chain traceability can be secured, achievable and infallible. The blockchain technology when combined with the cryptographic hash and the cloud storage provides the solution to provide information about the offer operation and integrity of data.

A. Role Assignment

This can bee defined as a role assignment to user.role assignment: this is defined as the roles being given to the users. Firebase is used to authenticate the user. Authentication or to be more precise verification of identities of a stakeholder through the help of an email based stock-in. The identification process will be good after good authentication process where unique user ID will be provided, which cloud be used in allotment of pre-established roles like distributor and retailer and farms. The role based access control does not restrict any players to get involved in illegitimate operations in the system.

B. Batch Creation and QR Code Generation

The key-in in the information on the production and crop and interface through the web would lead to the generation of new farm batch in the initial stage. The reference to the brand will be placed at the centre of the product. Supply chain containing Batch ID that had been created and programmed in a QR code is easy to mount with information about the next step.

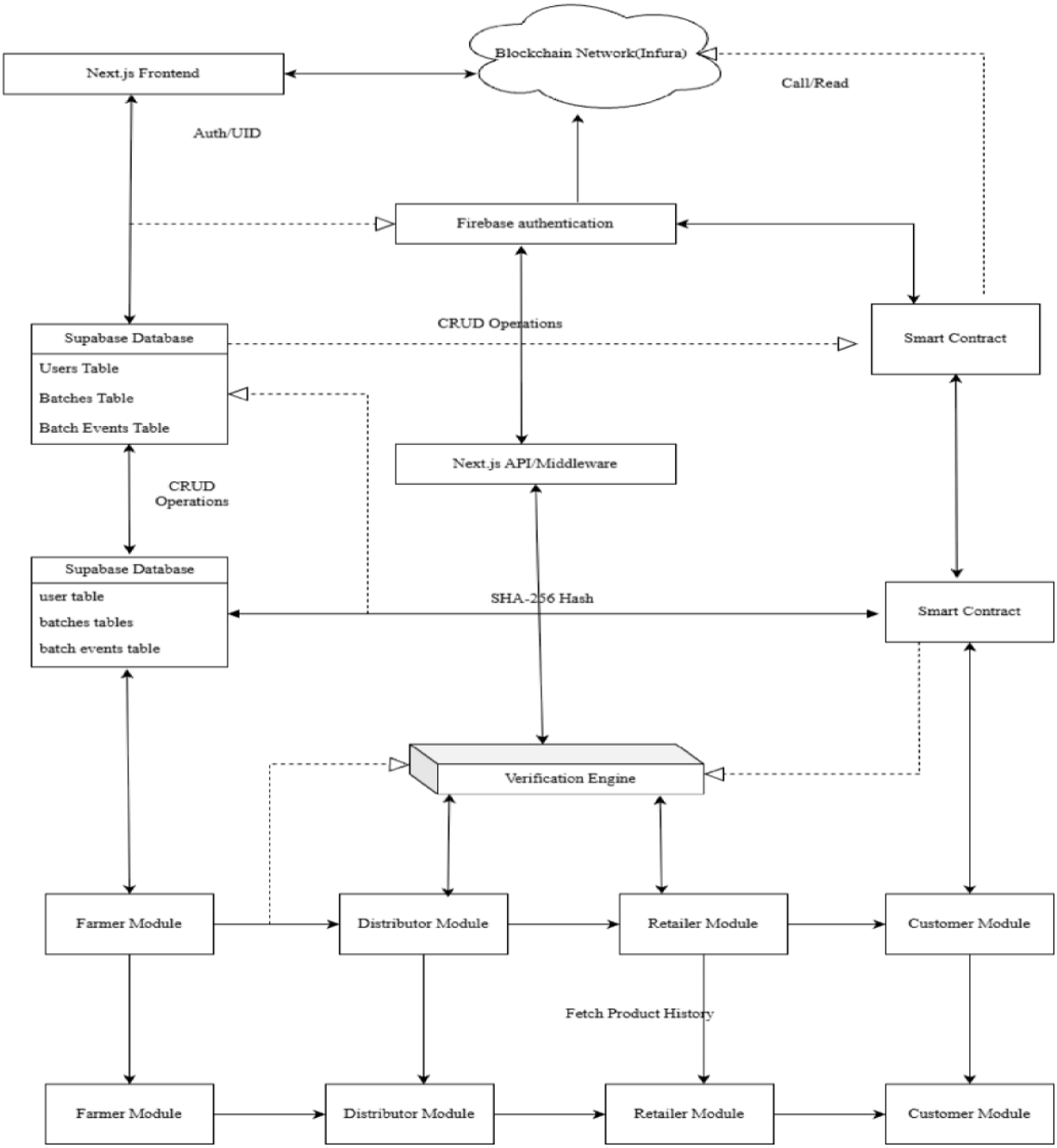

Fig 1: Blockchain Technology for Agricultural Supply Chains

C. Generation of Cryptographic hash

To guarantee the integrity of the data we will actually perform a cryptographic computation of all supply chain events of a hash the computation of all supply chain events of a hash computation being SHA-256 hash algorithm. The computation of the hash in question takes the following formula

H=SHA-256(Data json+ Timestamp+ Nonce)

The supply chain data obtained as a result of optimization is referred to as Data JSON, time when an event has been created is referred to as Time stamp and the final one is referred to as Nonce. Value chosen randomly by using hash so as to get collision of value

hash. The outcome of this is storing of information hashed(digital).

D. Blockchain Cryptocurrency Help Hash Store and Integration

Infura API, who assists in postulating one smart contract to Ethereum blockchain, saves the dderivehash values on Sepolia network. The foerunner of blockchain is a PoA. It involves consensus mechanism in offering swift, effective, and economical margins of ensuring transactions. Only spare metadata and cryptographic hash values are contained in the chains> Ensure the secrecy of information and reduce overhead costs to stores.

E. Supply Chain Event Notice Mechanism

New information concerning the vent will be available to the distribution and retailers that will be scanned by each organsizer as represented by the product scan. The supabase does not save the data on blockchain and leads to the re-emission of a new hash with the assistance of SHA-256 and puts a hash in the blockchain. Is is the append only property therefore, blockchain cannot manage the records that were already stored in the past.

F. Verification Logic

Once the manufacture QR code of a product is scanned by a consumer, he/she will access the system of checking. The application exploits the entirety of off-chain data and on-chain of Ethereum blockchain H with the assistance of supabase database. The computation of the hsh value also determines the same computation as it does in the application.

H_{local}=SHA256(D)

In a situation where the $H_{local} = H_{chain}$, they will establish the information of the product as genuine. The calculated and recorded difference in hash value fails to present the shortage of actual potential of data manipulability. It is a form of check which is not based on the name of the customer hence open and mistrustful.

Fig2:Security Analysis

V. RESULTS AND DISCUSSION

The paper in the given case demonstrates how the proposed blockchain-based agricultural supply chain system works, including the data integrity, traceability, security and scalability and the result of the experiment that was launched when the system was introduced.

A. System Implementation Results

The offered solution has been elaborated on the example of the Vercel platform, web-based off-chain decentralized application which is created with Next.js and firebase Authentication that authenticate the users and Supabase cloud databases that store the supply chain data. The blockchain layer is made according to the assumption of the smart contract that is created on the Ethereum Sepolio network with the assistance of Infura. The system worked well in one area which was the fact that it helped to generate both batch, QR code and generation to generate supply chain events and consumer-side events and consumer-side events to verify the A QR code of a given batch and follow through with the large number of scan events with no data loss or duplication. Append only paradigm made sure that historical records of the supply chain process were made available.

B. Data Integrity and Data Tampering

The integrity tests of the data were conducted through controlled experiments in which the off-chain data

was adjusted as every blockchain data had been stored in the hash. The modifications have been observed as soon as the manipulation has been made possible as the locally computed H local had no identical value as the on-chain H chain. This implies that the mutability of the hash of SHA-256 hash and blockchain is applicable to prevent the manipulation of unwanted information.

$H_{local}=H_{chain}$ => Advertised.

The data of the supply chain could be represented to indicate that the data are authentic in cases where no amendment was made.

C. Analysis of Scalability as well as Performance

By the fact that the cryptographic hash values were stored in-chain on the blockchain, this greatly decreased the amount used to fit the gas as opposed to that of storing the actual data in real-time which would be utilized to analyze consumers as compared to the lightweight hash registration which turned out to be the sole way through which the blockchain activities could be executed It was powered on the PoA consensus mechanism to draw a steady functioning on various updates of batches and least transaction delay. The scalability of the system as observed is evident in the fact that the system could support numerous batches and scanning events at the same time without distorting its functionality implying that the system could be successfully implemented in the real-life enterprise, which is the agricultural supply chain.

D. Traceability and Transparency Assessment

QR based traceability approach offers a convenient produce trace in the agriculture industry, both in relation to the farmer and the consumer. Each of the scans captured the past of the product within the batch and this generated a good picture of the time of the whereabouts of the product in the past. This added to the process of certifying the product to the customers and further usability and confidence.

E. Secure Discussion

To be able to warrant that the uploading of data as well as its access was not legal, firebase authentication was performed. SHA-256 hash algorithm used ensured the cryptographic security of the message in addition to the non modifiability of the stored hash. The hybrid architecture was able to off-set the security and performance with the layers being separated to save and authenticate information.

F. Comparative Discussion

The traditional centralized systems and IoT-oriented supply chain systems cannot be linked to the proposed system because it did not involve hardware, low costs of running the operations, and points of failure. The issue with the specified strategy is that cryptographic checks on the authenticity of the information are given in contrast to the current solutions that are based on central databases.

VI CONCLUSION

In this study, a blockchain- powered agricultural supply chain traceability system that ensures data integrity, transparency, and safe verification of farm-to-consumer agricultural products was introduced. By combining blockchain and cloud-based storage as well as cryptographic hashing, the proposed system manages to address the problem of data manipulation, problems with traceability, and lack of consumer trust in traditional supply chain systems.

Utilizing the Ethereum blockchain through Infura to store immutable hashes, Supabase cloud database to store data in the form of scalable off-chain, and Firebase Authentication to manage roles in a safe manner are all used in this solution. The SHA-256 hashing algorithm ensures strong data integrity and the PoA consensus mechanism makes it possible to effectively and inexpensively validate transactions. The simple and convenient interface of the tracking system based on QR code can be beneficial to all stakeholders, such as customers who can also identify the authenticity of the products without authenticity. As per the experimental findings, the hybrid on-chain /off-chain architecture ensures high degrees of security and traceability and significantly reduces the cost of transactions and blockchain storage overheads. The verification process boosts customer, distributor, retailer, and producer confidence by successfully uncovering any form of unauthorized changes to supply chain data.

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