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Integrated System for Management of Food Supply Chain using Blockchain

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Abstract: *According to WHO, over the past decade the South-East Asia Region has witnessed a staggering number of people affected by foodborne diseases. In 2010 alone, nearly 150 million people fell ill due to contaminated food, leading to a heartbreaking 175,000 deaths. The burden of this issue disproportionately affects young children, with 40% of foodborne disease cases occurring among children under the age of 5. It's worth nothing that malnutrition is also a significant problem in the region, and poor sanitation practices exacerbate this issue. Approximately 50% of malnutrition cases stem from unhygienic practices and life-threatening infections, such as diarrhea, rather than a poor diet. In these situations, a well structured integrated platform is required to monitor the food supply chain straight from the producer to consumer in a way that other government authorities can track the quality of the products of different producers. This paper is an attempt to create an SDK that can integrate with online marketplaces in order to trace the quality and quantity of the food products by storing the data of the entire supply chain using smart contracts and providing the data to the end consumers using ledger.*

Keywords: Blockchain, Etherium, Food Supply Chain, Cross Platform Application, Solidity

I. INTRODUCTION

In recent years, the rise of food-borne diseases has become a major concern, particularly in densely populated developing countries like India. According to data from the Integrated Disease Surveillance Programme (IDSP) from 2011-2016, food-borne outbreaks and acute diarrhoeal diseases accounted for almost half of all reported outbreaks.

To address this issue, the use of evolving technologies can be leveraged by both government bodies and citizens to monitor the food supply chain. By implementing a system that tracks the quality of food products from the manufacturer to the end consumer, future disease outbreaks can be prevented.

The application has a differential login. It is based on 2 profiles - 1) Manufacturer 2) Consumer

Manufacturers would monitor their suppliers and distributors, providing details related to the products they supply. Consumers can then access this information and purchase products from different manufacturers. Data provided by manufacturers would be stored in smart contracts, enabling verified bodies like the health ministry to trace back the records in the event of a disease outbreak. By doing so, the root cause of the outbreak can be identified, and steps can be taken to mitigate its spread.

Overall, this system can help to ensure that citizens have access to affordable, high-quality food while also promoting accountability and transparency in the food supply chain.

Blockchain is a distributed ledger technology that consists of three major components: blocks, nodes, and consensus mechanisms. Here's a brief explanation of each component:

- Blocks: A block is a digital record that contains a set of transactions. Each block is linked to the previous block in the chain through a unique cryptographic hash, creating a continuous chain of blocks. Blocks also contain a timestamp, which helps maintain the chronological order of transactions.
- Nodes: Nodes are the individual computers or devices that participate in the blockchain network. Each node maintains a copy of the blockchain ledger and participates in the process of verifying transactions. Nodes can

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be divided into two categories: full nodes and light nodes. Full nodes store a complete copy of the blockchain ledger, while light nodes store a subset of the blockchain data.

- Consensus mechanisms: Consensus mechanisms are the rules that govern how transactions are validated and added to the blockchain. The most common consensus mechanism used in blockchain is called Proof of Work (PoW). In a PoW system, nodes compete to solve a complex mathematical problem to validate a new block of transactions. Once a node solves the problem, the new block is added to the blockchain. Other consensus mechanisms include Proof of Stake (PoS), Delegated Proof of Stake (DPoS), and Byzantine Fault Tolerance (BFT).

In addition to these three major components, there are also other important aspects of blockchain technology, such as cryptography, smart contracts, and mining. Cryptography is used to secure transactions and ensure that only the intended parties have access to the data. Smart contracts are self-executing contracts that automatically enforce the terms and conditions of an agreement. Mining is the process by which new blocks are added to the blockchain through the use of computational power. All of these components work together to create a decentralized, secure, and transparent system for storing and transferring data.

II. ROLE OF BLOCKCHAIN IN FOOD SUPPLY CHAIN MANAGEMENT

Blockchain technology can potentially transform the food supply chain management industry by providing a secure, transparent, and efficient way to track the movement of goods from farm to table.

The use of blockchain in food supply chain management allows for the creation of a tamper-proof, decentralized database that records every step of a product's journey. This can include information such as the origin of the product, its production methods, transportation details, and storage conditions. All parties involved in the supply chain, including farmers, distributors, retailers, and consumers, can access this information in real-time, increasing transparency and accountability.

The use of blockchain technology can help identify and address issues such as food contamination, spoilage, and fraudulent labeling. By having a complete and transparent record of a product's journey, companies can quickly identify the source of any problems and take action to prevent them from affecting other products.

Furthermore, blockchain can help streamline the supply chain by reducing paperwork, eliminating intermediaries, and automating payment processing, inventory management, and logistics processes. This can lead to faster delivery times, lower costs, and increased profits for all parties involved.

Overall, the use of blockchain in food supply chain management can create a safer, more efficient, and more sustainable food supply chain, benefiting everyone from farmers to consumers.

III. ARCHITECTURE FOR BLOCKCHAIN-BASED FOOD SUPPLY CHAIN

Blockchain technology for food supply chain management involves a distributed ledger that records all food supply chain transactions and events. The ledger is comprised of encrypted data blocks linked in chronological order, each holding a batch of transactions validated through a pre-defined consensus protocol. Users interact with the blockchain through web and mobile applications specific to their role in the supply chain.

3.1 Main user groups:

- **Raw food suppliers** transact data on the food origin and movement across the supply chain.
- **Food manufacturers** provide information on the food product ingredients and manufacturing processes.
- **Food inspectors** and **certification entities** verify documents on the product's origin and quality.
- **Transportation providers** upload details on the location and storage conditions of food products in transit.
- **Food product distributors** trace food supply chain activities to assure responsible sourcing practices, food product quality, and safety.
- **End consumers** access details on food products' provenance to verify their authenticity.

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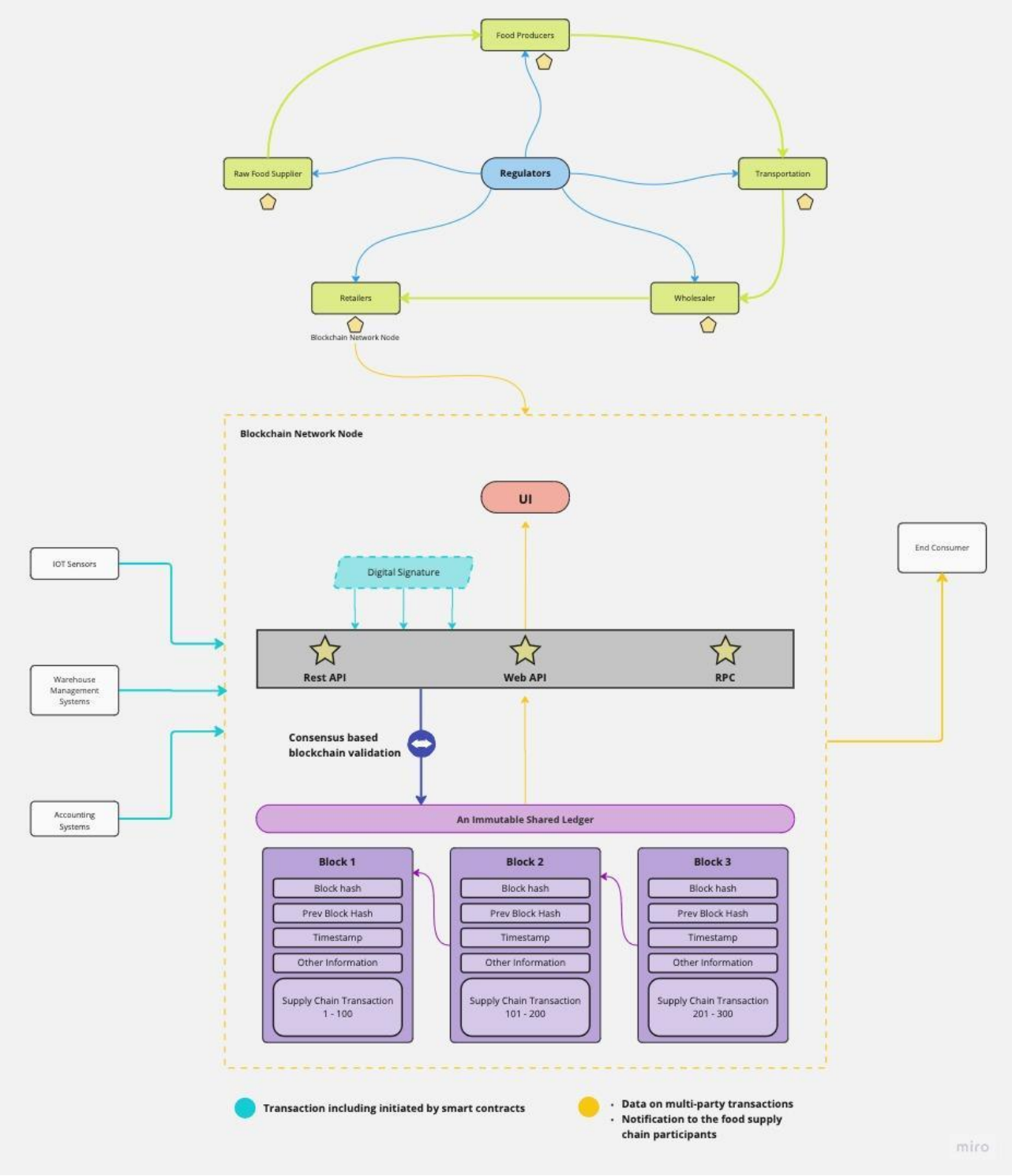
Flowchart explanation in the Figure below.



3.2 Key points of the Architecture

The architecture of blockchain in food supply chain management typically involves the following components:

- **Distributed ledger**: Blockchain technology is built on a distributed ledger, which is a decentralized database that maintains a continuously growing list of records, called blocks. Each block contains a set of transactions and a timestamp.

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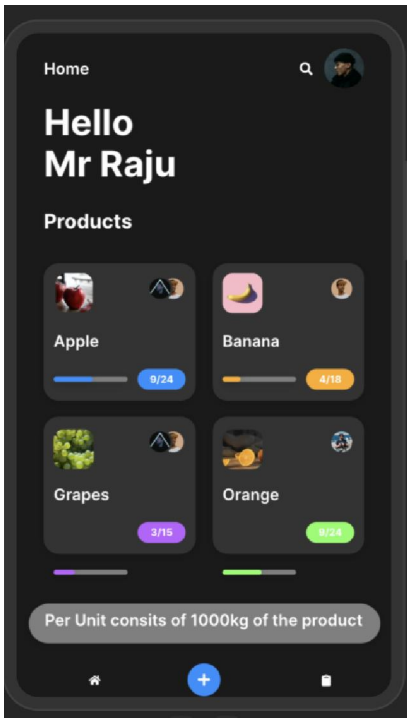
- **Smart contracts:** Smart contracts are self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. They are used to automate the execution of business processes in a secure and transparent way.
- **Nodes**: A node is a computer that participates in the blockchain network. Each node maintains a copy of the ledger and verifies transactions.
- **Consensus protocol:** The consensus protocol is used to ensure that all nodes in the network agree on the state of the ledger. There are different consensus protocols, such as Proof of Work (PoW) and Proof of Stake (PoS).
- **Public and private keys:** Each participant in the blockchain network has a public key and a private key. The public key is used to identify the participant, while the private key is used to sign transactions and prove ownership.
- **Data storage**: The blockchain stores data in a tamper-proof way, ensuring that the data cannot be altered or deleted without the consensus of the network.

In a food supply chain management system based on blockchain, each participant in the supply chain, such as farmers, processors, distributors, and retailers, would have a unique identity on the blockchain. Each transaction, such as the movement of food products from one participant to another, would be recorded on the blockchain and verified by the consensus protocol. Smart contracts could be used to automate the execution of business processes, such as payment and delivery, and to trigger alerts if certain conditions are not met, such as the expiry of a product. The transparency and immutability of the blockchain would enable consumers to trace the origin of the food products, verify their quality and safety, and make informed purchasing decisions.

IV. GLIMPSE OF THE APPLICATION



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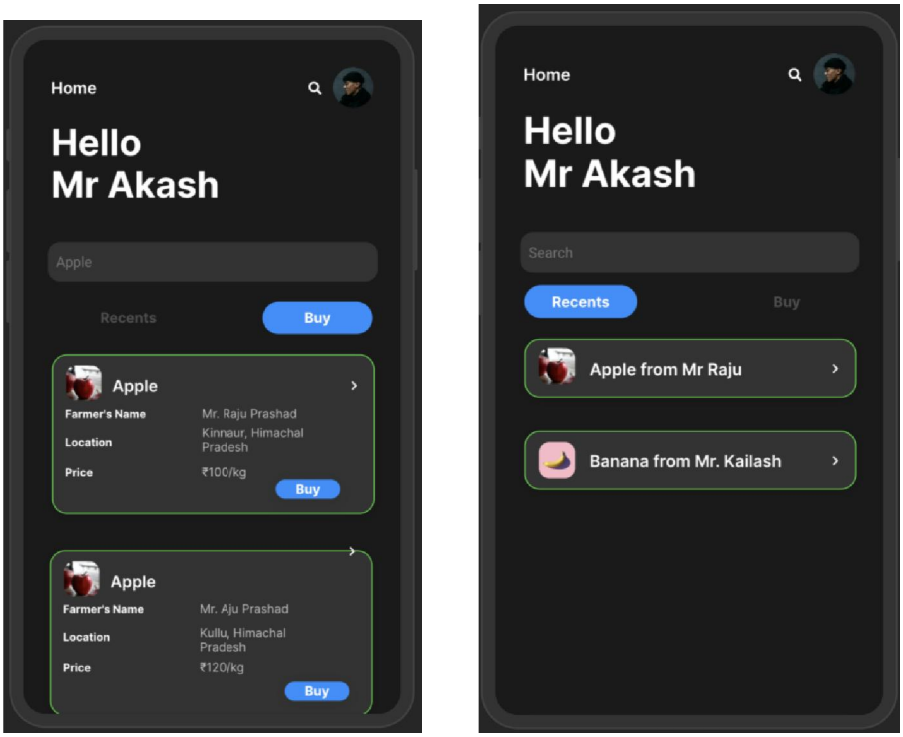

V. MAIN USE CASES

- **Food Supply Chain Control** - Achieving end-to-end traceability of multi-party transactions across all levels of the food supply chain helps to establish transparency and accountability. This streamlined approach allows for better control of the food supply chain and minimizes the risk of disruptions. By tracking food products from their origin to the point of consumption, it is possible to identify any potential issues and take immediate action. Such traceability helps to ensure that food products meet safety and quality standards and enables consumers to make informed decisions about the products they purchase.
- **Food supplier selection -** Storing food supplier pre-qualification data, essential documents, and performance indicators in a decentralized ledger allows for transparent supplier scoring and selection. This ledger enables multi-party supplier data monitoring, ensuring that all necessary licenses and certificates are up-to-date and that the supplier meets performance standards, such as on-time deliveries and quality claims. Keeping this information in a secure and decentralized location, it allows for more efficient and accurate supplier selection. This promotes transparency and accountability in the food supply chain, ensuring that only the most qualified and reliable suppliers are selected.
- **Food safety control -** Recording and monitoring data on farming practices, food product ingredients, expiration dates, storage, and transportation conditions helps identify potential spoilage and contamination points. This data enables the timely prevention of the distribution of unsafe food, ensuring the quality and safety of food products. By accurately tracking these factors, it becomes possible to identify potential areas of risk and take appropriate action to mitigate them. This promotes a culture of transparency and accountability throughout the food supply chain, from farming to consumption, and ensures that food products meet safety and quality standards.
- **Food quality control -** By recording and monitoring data on food quality control procedures throughout food processing, manufacturing, distribution, and other stages, it is possible to ensure compliance with global and internal quality standards. This data allows for automated compliance checks, which verify that food products meet these standards. Automating these checks reduces the risk of human error and ensures consistent, high-quality food products. Maintaining this data promotes transparency and accountability in the food supply chain, enabling consumers to trust that the products they purchase meet safety and quality standards.

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- **Food claim management -** Traceability of food provenance and supply chain transactions provides proof for dispute resolution (quality, authenticity) and minimizes recall risks.
- **Food labeling -** Keeping a record of food products' origin, movement, and transformation assures accurate product labeling and compliance with global and region-specific food labeling regulations. This record allows for transparent and accurate labeling of food products, ensuring that they are marketed and sold correctly. Tracking the journey of food products from their origin to the point of consumption, it promotes accountability and transparency in the food supply chain. This is important in maintaining consumer trust and complying with regulatory requirements for food labeling, which vary across regions.
- **Food fraud prevention -** To verify food authenticity and prevent fraud and counterfeiting, data on food origin and chain of custody is traced and stored. This ensures transparency and accountability in the food supply chain, enabling easy identification of counterfeit products. Tracking food products from their origin to the point of consumption helps to establish trust in the food supply chain and protect consumers from potential health risks associated with counterfeit products.

VI. KEY FEATURES

- **Automated record keeping -** All transactions between the food supply chain participants and relevant food product data from the connected systems (e.g., data on food manufacturing processes and product ingredients from ERP, sensor data on food storage conditions) are automatically validated, timestamped, and recorded in the blockchain.
- **Food supply chain traceability -** A distributed ledger available to all food supply chain participants provides an immutable record and real-time view of all transactions between the involved parties, including food purchase orders, transfer of ownership, transfer of responsibility, payments, recalls, and more.
- **Food provenance tracking -** Blockchain stores a complete history of data on a food product's journey from its origin through manufacturing, storage, transportation, and quality control processes to end consumers. Once recorded, food provenance data becomes immutable and can be accessed at any point.
- **A full audit trail for the food supply chain documents -** Blockchain records and stores data on all manipulations across the food supply chain documents, including those assuring the food supplier qualification (e.g., accreditations, licenses), food product origin and quality (e.g., certificates of origin, certificates of analysis), food product ownership transfer (e.g., bills of lading, receipts), and more.
- **Smart contracts -** Self-executing protocols (smart contracts) automatically enforce fixed actions, pre-agreed by the food supply chain participants, upon the pre-defined events (e.g., making a payment to the supplier upon product delivery, checking food safety compliance against required safety standards during food farming, processing, manufacturing).
- **Hashing -** The food supply chain data integrity is achieved with hashing. Each blockchain data block has an automatically generated unique cryptographic identifier (a hash value) and contains the hash value of the previous block. If data stored in one block is modified, the hash value in this and all subsequent blocks will change, which makes the data tamper-evident.
- **Configurable user access rules -** The food supply chains mainly rely on permissioned blockchains, where the rights to transact, view or share particular data can be configured for various food supply chain participants (e.g., suppliers, manufacturers, retailers).
- **Consensus-based data validation -** In permissioned blockchains, consensus on transactions validation and their storage in a particular order is achieved via selective endorsement, where only known and trusted food supply chain members with special rights can validate the transactions.

VII. CONCLUSION AND FUTURE WORK

After the successful usage of the current version of the application, we can privatize it as an SDK. We can involve the monetary transactions like we are doing with the food supply chain to secure the complete architecture of the application. NFT's (non-fungible tokens) can be introduced as a replacement of the ordinary monetary transaction

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acknowledgement. We can also provide better user experience to the end users with features like multi lingual support, interactive chatbot etc.

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