Consortium Blockchain Application for Agriculture and Food Supply Chain Management

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Abstract - *As the agriculture and food sector face many problems in the traceability of agriculture products and foods. In India it comprises of many small-scale farmers, they have many difficulties such as traceability of supply chain, quality and food safety, efficiency, less payment. To make agriculture and food supply chain management effectively, we use blockchain technology in our proposed system. Blockchain is an immutable, distributed ledger-based technology by which the transactions could be done in a decentralized way without any intermediator. Blockchain can increase the efficiency, reliability, and transparency of the supply chain management. We use Hyperledger fabric blockchain technology by which we build a consortium-based blockchain network. All stakeholders in the supply chain such as farmer, production unit, distributor, the retailer can interact with the system in an immutable and decentralized way. Hyperledger Fabric has many advantages than other blockchain frameworks in performance, scalability, security. We make the supply chain of agriculture and food effectively with fewer expenses.*

Key words: **Blockchain, immutable, decentralized, distributed ledger, consortium, Hyperledger fabric.**

1. INTRODUCTION

There are many challenges in the food supply chain like food traceability, correct fairs, food safety, lack of knowledge of their supplies. As there is traditional supply chain system in which it not beneficiary due to centralized system.

The traditional supply chain management is built over a centralized system and the data in those system is not tamper-proof. Since it is centralized system, the individual participants such as farmer, producer, retailer and distributor can't able to know how their products is being processed. Thus, a Blockchain based decentralized system solution is implemented for easy traceability of products and to have a tamper-proof record.

A Blockchain is a growing list of records, called blocks, which are linked using cryptography. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data. Blockchain has been in a lot of fields these days. This is due to the immutable records, decentralized system and distributed ledger-based storages characteristics. We use this for efficient supply chain management of agriculture and food products.

The blockchain technology was implemented in older systems. But major decentralized system was implemented in Ethereum platform. Ethereum platform is easy to implement, but has many disadvantages such as low transaction rate, public blockchain platform, no privacy of data, no reliable consensus protocol.

We built the traditional supply chain system over Hyperledger fabric blockchain framework which is enterprise-grade, permissioned blockchain. Various actors such as farmer, producer, distributor, and retailer interact with the system for efficient supply chain management of agriculture and food products. The distributed ledger technology helpful in updating each peer database every time a transaction is done in the blockchain network.

We design the system as a web application, in which the individual participants such as the farmer, producer, distributor, retailer can add their product records and trace it using querying those products.

1.1 Literature survey

The study of the existing system is made on different system supply chain solutions. The major system for supply chain uses Ethereum blockchain framework. Kentatoh Toyoda proposed a system called "A Novel Blockchain-Based Product Ownership Management System (POMS) for Anti-Counterfeits in the Post Supply Chain [1]", which uses RFID for data acquisition and used Ethereum smart contracts for implementing the blockchain. In real world system the RFID is used in many IoT based sensor, which collect the data of the different devices and enter it into the blockchain network. In real-time production environment, different sensors are used for tracking different objects such as the weather details, in producer units they use many sensors to track the food details. For tracing the supply of soybean, a blockchain-based supply chain system has developed by Khaled Salah [2]. This Ethereum smart contracts are used in another two systems "Smart Contract-Based Product Traceability System in the Supply Chain Scenario [3]" and "Modelling food supply chain traceability based on blockchain network [4]". Though it is easy to implement, it lacks in many properties in terms of transaction rate, privacy and type of consensus protocol. Another system is implemented by Prabu Devan S, they implement this supply chain using the Hyperledger Sawtooth in the cloud. It also uses RFID to collect data and integrate those data into the

blockchain network. The cloud can be used for scalability of the blockchain network. The main disadvantage of blockchain is scalability and performance. This can be done using the cloud technology. Thus, we use this Hyperledger Fabric framework to overcome the above problems in the supply chain management.

2. TECHNOLOGY

The system is implemented over the enterprise-grade permissioned blockchain framework, Hyperledger fabric. The Hyperledger fabric framework has many advantages than any competing blockchain framework.

2.1 Blockchain technology

Blockchain is a technology by which a growing chain of records which is linked using the cryptography called a hash function. Blockchain technology is a decentralized, and a distributed ledger-based system in which the record stored are immutable. The records in the blockchain is stored as from (sender), to (receiver), timestamp (time at which the transaction is done). These data have been stored as records and a hash function is generated for those data. In blockchain the data is stored as a block. The first block in the blockchain is called Genesis block. It doesn't have any hash value or previous hash value. Then the following blocks contain previous hash value and a hash value of its own. These are linked in a chain and this chain is called blockchain.

The immutable records in the blockchain provides the advantage such as tamper-proof data. If a data is record into the blockchain it is difficult to change it. Thus, it provides high security of tampering the data. The distributed ledger technology is where replication of the same data to all node in the network is done. Thus, it provides fault tolerance and data loss. This type of distributed ledger system needs to be implemented in peer to peer communication systems. The peer to peer communication refers to that there is no centralized system to manage it. The systems need to communicate with each other in a decentralized way.

This blockchain technology was first coined by Satoshi Nakamoto by means of implementing Bitcoin. Bitcoin is a cryptocurrency; in which it is used to send the money between user to user without any centralized systems like a bank. Now, this blockchain technology is been implemented majorly in supply chain management. The use cases of blockchain technology are:

- Supply chain management
- Healthcare
- Energy
- Transportation
- Financial sectors

Now these blockchain technology is being implemented over many applications and they are mainly used in IoT based application for tamper-proof of data. We implement this blockchain technology in food and agriculture supply chain management in which gives easy traceability of the products between the different actors in the supply chain.

2.2 Hyperledger Fabric framework

Hyperledger framework is an enterprise-grade blockchain framework used for implementing the blockchain over a private network. This Hyperledger Fabric blockchain is a permissioned blockchain framework, which is meant to build only for enterprise purpose.

The Hyperledger framework is an open-source blockchain project maintained by Linux Foundation and many leading companies contribute to this open-source project. It has many advantages than others by means of privacy, high rate of transactions, pluggable consensus protocol. For an enterprise system, the system must be secured. Thus, here the security is provided by means of CA (Certificate Authorities) and MSP (Member Ship Providers). This Hyperledger Fabric can execute 3000-3500 transactions per second, which is higher than other blockchain frameworks such as Ethereum and Bitcoin. It uses a different strategy as Execute-Order-Validate mechanism. Another main advantage is that the smart contracts can be implemented using of known languages such as GO, JAVA, node.js and python. No need for special languages to implement it.

3. IMPLEMENTATION

The proposed system is implemented over the Hyperledger blockchain framework. The implementation process involves different stages. The architecture of is shown in Fig-1. The system has been module into four different modules. They are:

- Web application module
- Fabric client module
- Security module
- Blockchain network module

Fig-1: Architecture

3.1 Web application module

The user interface for interacting with the blockchain network has been built. This allows the different participants

in the system such as the farmer, producer, distributor, and retailer to interact here. This user interface is built as a web application in which different forms are used to enter and retrieve data from the blockchain network.

The web application is built using the Angular framework. The Angular is chosen because it is easy to implement the server-based application, dynamic web pages, speed and performance.

Each user in the system has a unique identity. They use their username and password for login into their system. This will direct to their peer system. As in the case of the farmer he has the form to create the product he produced on his farm. It contains details about the product id, name of the product, the date is produced. He can also create a shipment to producer. These details are stored into the blockchain network. He can able to query the products he created into the blockchain network. In the case of the producer, he also creates the products produced, creates a shipment to distributer details, query all those data are done here. If the actor was a distributor, he can only create a shipment to retailer and query those data. If he was a retailer, he can only query those products he received from the distributor. Every time a transaction is executed it has been stored into the blockchain network using fabric client SDK. This has been implemented in the fabric client module.

3.2 Fabric client module

The user interface helps in interacting with the blockchain network. The blockchain network works on a different platform as frontend. To interact with blockchain network we need a middleware to communicate between the user interface and blockchain network. The Hyperledger fabric provides an API needed to interact with the system. This API can be built using JAVA, node.js. Here we use node.js API.

The Hyperledger fabric provides an API called fabric-client API, which can be used to execute operations in blockchain networks. This API can be used to enrol the users of the blockchain network, execute the chain code transactions, connect to the network channel. For each participant in the system, they execute the chain code using different API services. This act as a server-side application. The express node.js framework has been used for interacting with the Angular user interface framework.

3.3 Security module

As mentioned above, the Hyperledger Fabric is a permissioned blockchain. Thus, security is the main concern. Hyperledger Fabric provides security using CA (Certificate Authority), MSP (Member Ship Providers). This Hyperledger fabric provides X.509 certificates through CA. The Member Ship Providers provides policies to access different system in the blockchain network.

In production, they develop X.509 certificates as original, for project purposes, the Hyperledger Fabric provides a tool to generate the security credentials. The security credentials include certificates for different users, membership policies,

public and private keys. The cryptogen tool is been is used to provide these security credentials.

The first block in the blockchain is called the genesis block. This is the block from which the chain of blocks connected using hash functions. The genesis block doesn't contain the previous hash. This genesis block contains the different membership policies for the nodes in the blockchain network. This is generated through the configtxgen tool. This tool is also used to generate the channel for the execution of the transactions and communication between the nodes.

3.4 Blockchain network module

For a production system different system can be made a setup for communication, for a project or experiment work the Hyperledger Fabric framework provide docker based setup for the different node in the system. In Hyperledger Fabric, we have two main nodes, one is the orderer node, and another one is the peer node. The orderer nodes are used for communication services in the blockchain network. For a single organization, we can use SOLO messaging service. If a multi-organization, then Kafka or raft ordering services can be used. In our system we setup one orderer for four different organizations. The peer node is the individual node for each organization. Our system has four different organizations as farmer organization, producer organization, distributor organization and retailer organization. The blockchain network for is shown in Fig-2. Each organization has an individual admin user and number of users. This is set up using docker images and docker-compose file, which contain the specification of different nodes in it.
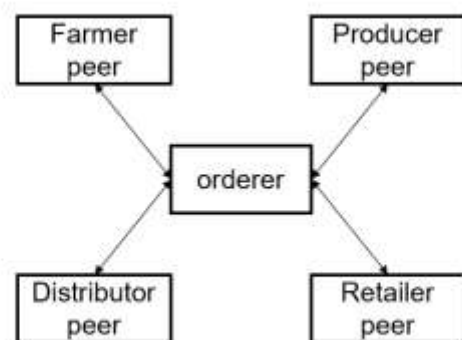

Fig-2: Blockchain network

4. PROCESS

4.1 Creating a product record

In the system the farmer can create the product he produced in the farm and the producer create the product he produced. They both log in to their system by their identity. Then they navigate to create a product page, where they create their products. This created product is stored in the blockchain network. The farmer and producer can view the products he wanted by querying it.

4.2 Transporting the product record

After creating the product, when a farmer transports the product to the producer, he creates a new record of transaction using the transport form. This transaction is stored into the blockchain network. This same process is done for producer and distributor when they transport products to the distributor and retailer respectively.

4.3 Querying the products

For getting the information about the products, the details about the transaction can be queried from the respective participants. If he is a farmer, he can query the product he created, and transactions he has done to the distributor. If he is a producer, he can query the product he created, the farmer products created, and the transactions he has done. If he is a distributor, he can query the transactions from the producer and to the retailer. If he is a retailer, he can only query the transaction done to him by the distributor.
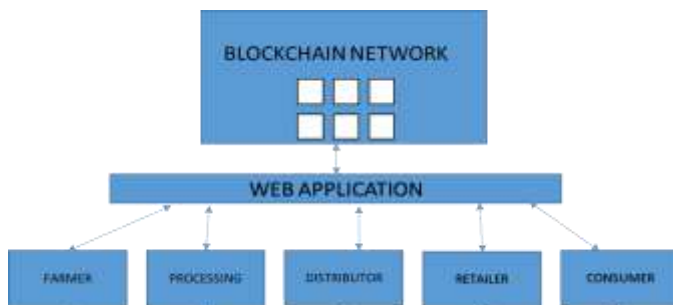

Fig-3: Supply chain process

5. CONCLUSION

The traditional supply chain management in the blockchain using Hyperledger Fabric framework and results in an effective supply chain system, with immutable records, easy traceability of products, and peer-to-peer communication between the participants. In future it can be integrated with the IoT sensors to automatically collect the data and send it into the blockchain network.

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