A Review on Supply Chain Management In Agriculture Empowered by Ethereum And IPFS

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***Abstract*— Supply chain management(SCM) is the process of organizing flow and handling goods and services, which focuses on transforming raw material into finished goods. In the field of agricultural SCM there are many problems such as data handling, logistics management, buyer-supplier relationships, food safety and technological difficulties in India's agricultural SCM. Effective supply chain management reduces waste, cost, time in production, logistics and supply chain environment. The supply chain management system that is to be built will focus on aspects such as resource planning, input management, growing of crops, transportation, logistics, storage, price allocation along with performance indicators, standardization of quality and prices. Hence coordinating, maintaining and making sure that all activities in the supply chain are synchronized. It ensures that no actor of the system is dominated by others. A review on SCM in agriculture, its drawbacks, and the solution to overcome the drawbacks are presented in this paper.**

Keywords*— *Supply Chain Management; BlockChain; Ethereum; Agriculture; Transparency; Traceability, Performance Measurement.

I. INTRODUCTION

India is one of the largest producers of fruits and vegetables. The most prominent reasons for production loss from a farmer's perspective includes middlemen marketing, lack of a proper storage system, huge transportation expenses and arrangement. An efficient process of marketing that uses the latest technologies such as blockchain and web-applications, increases the level of profit for farmers by decreasing the commission losses due to middlemen. Traceability is a concept that helps us in knowing the details of a farmer (participant of a network), source of the item, produced time and harvested time, etc. It is very important to have traceability in the food supply chain management to provide food safety in the system. By the use of decentralized systems, the transparency gets increased which makes people aware, producers to consumer's satisfaction will increase and it improves the communication between stakeholders. Achieving food security is all about having traceability and increasing agricultural production. Bitcoin is a crypto currency, which implements blockchain technology and does not require any third party for financial operations. Blockchain has Distributed Ledger Technology(DLT) that does not allow any single node to alter the records present in the blockchain, since data needs to be synchronized and hence the network becomes more transparent. Implementation of DLT allows customers to capture the lifecycle of products. As data of the entire system, data of the supply chain is stored in a distributed way, there is a lot of scope for transparency and traceability. Another important aspect of the supply chain management application will be its data storage and for that IPFS comes to the rescue. Day by Day the amount of transactions generated is increasing exponentially and one of the main concerns for blockchain technology in this regard is the storage facility. The append-only nature of blockchain makes it difficult to handle big data and file systems. So it is necessary to move some of this data to off-chain. This will reduce blockchain size and decrease the rate of growth of the chain significantly.

II. ORGANIZATION

Section III talks about the different areas that are researched and the insights that we have obtained from these papers. It mainly covers some basics of Bitcoin and Ethereum Blockchain in the first subsection, in the second subsection we have discussed the off-chain data fetching architecture for Ethereum Smart Contracts with oracle as a reference architecture, the third subsection emphasizes how supply chain management works in Agriculture, in the next few subsections we also look at traceability, performance measurement in supply chain management. We will look at how distributed file storage access framework using IPFS and Blockchain, helps us to solve storage issues in the blockchain. Section V summarizes few of the drawbacks of the existing system. Section VI provides a quick overview of the technological dependencies that might be required to come up with a better solution to problems discussed in earlier sections. Section VII is about the conclusions and insights that we have drawn from the concepts that are discussed in previous sections .

III. LITERATURE SURVEY

A. Bitcoin and ethereum blockchain

Nakamoto's idea of the electronic transaction process was completely new and innovative compared to what we had traditionally for years [10]. Nakamoto has defined the term electronic coin [10] as a chain of digital signatures. In Bitcoin, the coin owners digitally authenticate by signing a hash of the previously completed transaction and add a public key of the next owner to the end of the coin. The person who receives the coin next can go through the signatures to authenticate the legitimacy of the chain of ownership [10]. According to Satoshi Nakamoto's [11] "white paper

is often credited as a catalyst to the current blockchain revolution, the Ethereum Whitepaper was the biggest breakthrough in unlocking the power of decentralized technologies". Ethereum was found by Vitalik Buterin and is the second-largest blockchain next to bitcoin. The main aim of bitcoin was concentrated on the construction of a system for peer-to-peer digital currency transfer, whereas Ethereum was built to provide a framework through which we can run all our DApps(Decentralized Applications). In Ethereum, Smart Contracts can be written in a Turing-Complete language which gives developers full access, a range of options and tools to build required Smart contracts just the way they would do it any other programming language. When Ethereum was released people saw this as an advancement in the field of cryptocurrency and the advantage of a high-level programming language such as solidity was brought to the table. Vitalik Buterin talks about state transition where a distributed ledger moves from one state to another by the decision of the whole network. This injects trust, transparency, and immutability into the whole system.

B. Off Chain Data Fetching Architecture

Some components of an application may need data fetching and send to an external source, which means Off-chain data handling in Ethereum is necessary. This section proposes such an architecture [7] of data carriers for Ethereum smart contracts that would not depend on Ethereum node to monitor events with little more deployment costs. This involves interactions of computation source, Ethereum node callback, monitor the smart contract, contract developer register, and fetch of an external data source [7].The architecture contains three components: Mission Man- ager, Task Publisher and Worker. Mission Manager receives missions registered by users. It contains the event hash and contract address, way to respond to the event, along with the queue channel response for the event. Missions are stored in a database. Task publisher is implemented by Node.js. It clears irrelevant transactions, assigns generated tasks to work, captures event arguments, and new block transactions are collected by the publisher. Worker consists of 2 modules: execution module and transaction module. It executes the receiving command to obtain data.

C. Supply Chain Management in Agriculture

The supply chain of agricultural products seems to break due to several factors in recent days. The survey below determines the different ways in which blockchain technology can be incorporated into the agricultural supply chain such that the entire process functions transparently. Our traditional agricultural supply chain consists of various intermediate agents to realize a profit whereas producers incur heavy loss. Market trends, seasonal changes, pricing are some of the key parameters in the agriculture supply chain. In the supply of agricultural products, processors and traders undertake market research. Blockchain ensures the data is immutable at any point and is time-stamped. The entire network is very fragmented and smart contracts can be utilized. Some major problems in India's supply chain management system in the field of agriculture: Using blockchain technology to track the agricultural-food supply chain: By eliminating the need for third-party representatives [1], blockchain technology has its impact on Supply chain HACCP (Hazard Analysis and Critical Control Points). supply chain traceability which is used for food safety mainly focuses on transparency. Smart Contracts are used to secure data origin using the OPM (Open Provenance Model). [1]. Supply demand in the agro-food supply chain: There are issues in the Supply Chain, such as a sudden rise in demand for a product and the product running out of stock. Farmers (producers), dealers, and transportation companies are all involved in supply chain operations and must work together to provide a product to the consumer that meets their needs. The standard supply chain had flaws, such as no guarantee of food safety at many stages and a failure to provide accountability. Some of the disadvantages are removed by using blockchain as a shared ledger over a distributed network.Supply chain management from the manufacturing industry's point of view Buyer-supplier relationship is very important in the supply chain system. From the past few years, the Buyer-Supplier relationship has increased its attention. "The higher level of shared information and communications among the supply chain partners lead to improved collaboration" [2]. "Integration of Supply chain is supported by many of the enablers like Information Technology(IT)" [2].Fear of information system failure, disparities in trading partner capacity, and a low level of supply chain integration are some of the obstacles to supply chain integration. This is because when you are bringing the smaller things together and making it as one system, there will be a chance of loopholes in the system. We need some industries to get the review from the people like buyers, sellers, customers, etc. Selected

sectors from the Indian Manufacturing Industry are:

1) Engineering sector
2) Automobile sector
3) Fast Moving Consumer Goods sector
4) Process sector

"Among these four sectors, the automobile sector is seen as a flagship bearer frequently regarded as a barometer measuring the current wealth of a nation's economy" [2]. We are going to include Automobile Manufacturers and Automobile component suppliers from the Automobile sector for the survey. The important features of the fast moving consumer goods sector (FMCG) [2] are the need for food safety traceability and commodity-oriented business units. After selecting these sectors there will be some survey questions that are going to be asked and the rating needs to be given for each question by the people based on their satisfaction with the services.

Table 1. Comparison of Bitcoin blockchain and ethereum blockchain:

C++ is the programming language used for scripting.	Ethereum can be coded in Turing Complete Languages.
Handling smart contracts is not easy.	There is good support for working with smart contracts
A block in Bitcoin takes 10 minutes to be added into chain.	A block in ethereum takes 14 secs to be added into the chain
Reward halves every 210,000 blocks.	The reward do not halve, they remain constant.
As a consensus method, Bitcoin uses proof-of-work.	Ethereum actually employes proof-of-work, although it is in the process of moving to proof-of-stake.
A maximum of 21,000,000 can be created.	There is no limit for ether creation.

D. Traceability in Supply Chain Management

For the terms supply chain and supply chain management different propositions have been proposed by authors of [9], defines the supply chain as the "direct involvement of three or more entities in the whole flow of products, finances, services, and information from the origin to the end, and the supply chain management as the functions required to manage the flows, aiming to improve the whole supply chain and long-term performance of individual entities"[9].

The authors in [9] mentions six important elements of traceability including:

i. **Product traceability**: This traceability explains the tracing of the physical location of the product.
ii. **Genetic traceability**: This traceability tells about the genetic composition of the product .
iii. **Inputs traceability**: This traceability will give the information about origin and type of products.
iv. **Process traceability**: This traceability explains where ,how and when the product has been produced .T
v. **Measurement traceability**: Works on comparing individual measurement results to accepted reference standards through an unbroken chain of calibrations.
vi. **Disease and pest traceability**: This traceability will show how the bacteria and other microorganisms are handled .

The author[9] mentions different approaches for traceability. They are centralized, linear, and distributed. A centralized system includes a shared database that will become the source of data and this approach has its limitations due to factors such as storage place, security concerns, etc. A Linear system is where each stakeholder records his data and the part of data will be transferred whenever asked upon. In distributed systems, a traceability system such as blockchain's distributed ledger will take data handling and maintenance. Out of all three Distributed approaches is the most favored one but difficult to bring it to practice.

Requirement of optimized supply chains led to trials for traceability [8]. The ultimate focus was to learn maximum about the Blockchain technology and figure out the aspects that can solve the traceability problem. The most suitable approach is to connect both the Supply Chain Actors (SCAs) and product identifications using digital certificates [8]. The solution can be a complete traceability system that provides both SCAs [8] and the customers the highest level of traceability.

A conceptual framework was needed to be derived for implementing SCM with more complete traceability. The core components are provenance, chain of custody(COC) and traceability.

E. Improvement in Capability of online forensic

The digital platform of blockchain must integrate with resources in open internet legal[3], which enables to establish a digital asset dispute refining methodology. Transforming real assets into digital assets plays a key role in enhancing trust. The creation of the electronic warehouse receipt's traceability feature will aid in the improvement of the warehousing process, quality inspection, inventory counting, products transfer, and delivery.

Blockchain and its role in information security:

The use of blockchain technology to secure food supply data: People's health and safety are at risk due to the noisy buzzing issue in food safety. Many countries have researched, built, and operated traceability systems to ensure that product quality, safety management, and control are optimised. Information security in blockchain:Building an agro-food supply chain traceability system can be considered an urgent task as conventional management and traceability logic is unable to meet the demands of supervision and the fast-changing food market[4]. Governments, businesses, and consumers all profit from blockchain technology. The technological aspects of the blockchain provide the government with new creative concepts while also strengthening the conventional government structure.

F. Performance Measurement in SCM

The core dimensions of supply chain success that are measured in SCM are efficacy and productivity. The former refers to the degree of which a set target has been met, whereas the latter refers to the amount of inputs used in relation to a given level of outputs. There are two kinds of performance measurement aspects as per [6]: external performance measurement and internal performance measurement.

External Performance Measurement**:**

The details for analysts and investors in the company's reported financial statements is the parameter used for external success assessment. The emphasis has been on stockholders, analysts using financial reporting, but there is an increasing need for businesses to evaluate their success in comparison to

their rivals and the world's best corporations[6]. Types of benchmarking:

i. Internal benchmarking: In this type of benchmarking, operations within one company are compared. E. g., the effectiveness/efficiency of one business unit within an organization is compared with another business unit.

ii. Competitive benchmarking: This benchmarking involves going outside the company to direct competitors for comparison. E.g. two companies selling similar products can implement this benchmarking.

iii. Functional benchmarking: This is a type of benchmarking wherein common functionalities/features of a product from one company are compared with functionalities of product belonging to one of the contemporaries. Comparisons are made on the basis of specification details and their value propositions. .

iv. Customer benchmarking: This compares performance against customer expectations. It is employed by the most successful companies. This sort of comparison, under the title of market research, has been conducted by many organizations.

Internal Performance Measurement:

This aspect focuses on identifying a critical area of interest that enhances entirely the supply chain objectives of customer service and finances. An integrated performance measurement system needs to be designed for the provision of data insight that will prompt people to proceed in direction of improvement. The following steps are included in developing a supply chain output measurement:

Identifying the core elements of customer service in each focused market segment and establishing goals for each aspect. These priorities can be broken down into concrete targets for each supply chain connection using the stepwise decomposition method. These objectives are eventually converted into specific primary success metrics, such as efficiency, delivery, cycle time, and waste. The ultimate goal of this strategy is to ensure the implementation of an interconnected supply chain output measurement scheme, eliminating the situation where specific functions are calculated and thereby handled in isolation.

G. IPFS and blockchain

IPFS works using the DHT(Distributed Hash Table). Compared to BitTorrent and Git file, it is not only more productive, but also an efficient storage system. IPFS is also known as a version control system which provides features like scalability, security, reliability which is very rare to be seen in file sharing and storage systems. The fact that every file in IPFS has a unique hash ensures the originality and uniqueness of the network. Once the IPFS hash is computed, this hash will be broadcasted to the entire network, ensures consistency in the network and in turn among peers. The IPFS contributes a large throughput, content-addressed block storage model which confirms the security aspects of transactions.

Key features of IPFS as mentioned in[13]:

1. Hashing: IPFS can use different kinds of hashes to locate files with its multi-hash format. The three fields of multi-hash are as follows: The first one denotes bytes in length and also speaks about the kind of algorithm used (SHA2, SHA3, etc.), the second field denotes the size of the hash which is one byte. The size of the hash will already be in the second field and we can find the hash on the third field.

2. Garbage collection: Users can pin or unpin in their files in IPFS. The block of files that is unpinned is removed by the garbage collector. The files pinned by the user are always retained. The files that are not removed are pinned by IPFS. The user can pin/unpin a file using an if pin. Using the ipfs-add-pin command one can pin files in IPFS. The concept explained here is that code moved off-chain is identified by its 32-byte SHA256 hash.

3. Block reuse: IPFS stores data in form of 256 KB blocks, this provides a workaround to save some space in the network. If two or more contracts have the same bytecode, same functionality, which is more likely in some situations, and the size required for one such contract is less than half of 256 KB then two or more contracts can take the same block with the same hash. This will not create a hash collision but save space on the network and saves an extra hash that would have been generated otherwise.

Reasons for using IPFS in blockchain

1. To increase the integrity of Transaction: The integrity of transactions in IPFS content-addressed systems will be increased by creating a unique hash for each file using algorithms such as the one mentioned above. The Hash produced IPFS by this procedure adds durability and reliability to the transactions.

2. Easy to access transaction: In the IPFS distributed network, once any node in the network owns a copy of the file and its hash, any peer can access the file. The important thing to notice is that if a transaction's hash gets updated then automatically the transaction gets changed or updated without changing the peers connected to the IPFS hash.

3. Easy to distribute transaction: Peers can access the files to the system and broadcast the file content to other peers on the network. The PIN command will help to broadcast the file content to other peers.

IV. Access of Bandwidth by IPFS

Randhir Kumar and Rakesh Tripathi[13] speaks about how data is being stored, how it is being retrieved on a distributed network using IPFS that has two categories of bandwidth, 'IN' and 'OUT'. 'IN' refers to bandwidth occupied when the transactions are uploaded or stored into the IPFS network. 'OUT' is the bandwidth occupied when the transactions/files are fetched from the IPFS network. The below diagram shows the difference between the 'IN' and 'OUT' bandwidths.

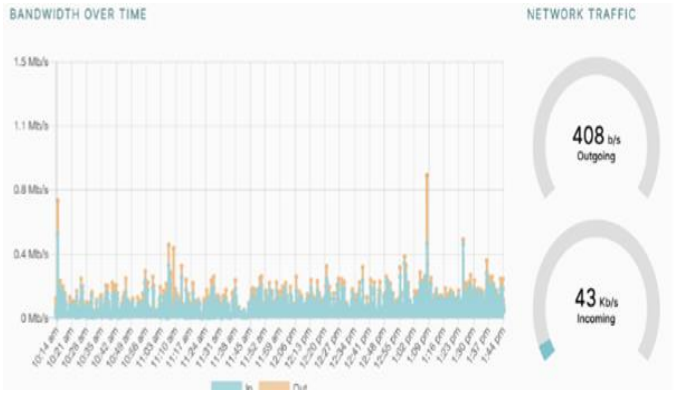

Fig. 1 Image showing IN and OUT bandwidth

V. Drawbacks of Existing System

From the study we have done on the papers listed in references, few prominent drawbacks in organizing a supply chain management in Indian agriculture are:

1. Unplanned number of intermediaries[2]: This will lead to cost inflation even by multiple folds sometimes which can result in infeasible cost scenarios in the market. This scenario may also lead to tampering in market supply-demand to create variations in cost.

2. Source of traceability[2]: Although Blockchain is a great platform, if the source of data fed into the system is not reliable then traceability may be compromised in the system.

3. Data exposure in IPFS[13][14]: The data stored on IPFS is great to take data off-chain when using blockchain solutions, but it's only secure until people find the hash. The content under the hash is not encrypted and can't be concluded as completely cyber secure.

4. Performance measurement in the chain[6]: We have seen a lot of performance measurement parameters and aspects in[6], but creating a standard and benchmark across the agriculture industry is a challenge.

VI. Solutions to Overcome Challenges

To solve the problems listed and to integrate the activities of the supply chain, we have designed a workflow mechanism, with help of Ethereum blockchain (along with related tools). Fig. 2 shows this mechanism in brief. As we can see, there are mainly 6 actors in the application. Farmers are producers of the chain, Suppliers are actors who supply raw materials or agricultural equipment for a farmer. Agricultural consultants are people with scientific expertise in the agricultural field helping farmers in optimizing their resources for maximum usage. Transporters are people who move products between two points along with optional storage and warehouse facilities. Distributors are the actors who buy from the farmers and this is where it reaches end-users. Funders the actor who contributes to the public funding aspects of a crop, and this is an optional feature in the chain for farmers. This is the basic idea which when built upon is expected to lead to an efficient supply chain in agriculture.

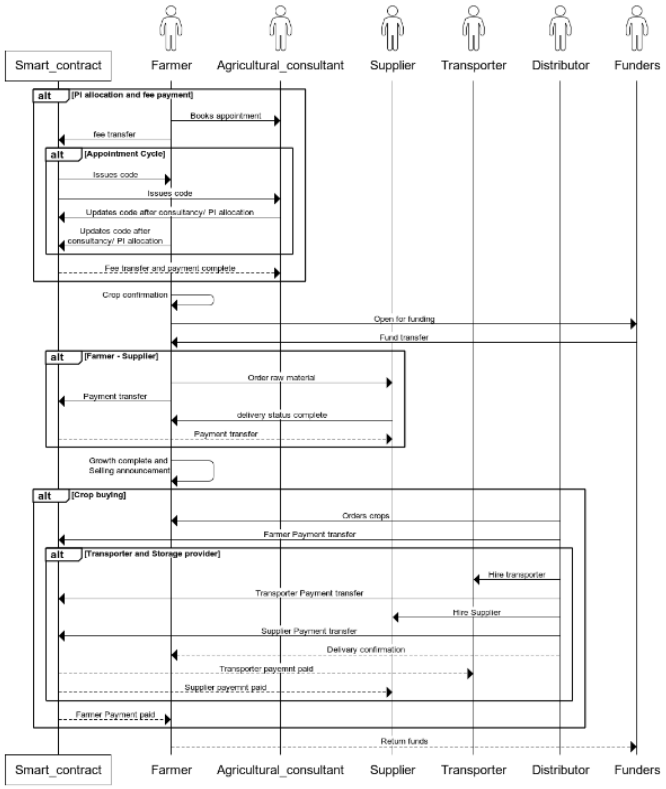

Fig.2 Project Workflow

A. Infura API

When an IPFS node is running as a daemon, Infura [15] creates an HTTP API that allows users to control the node and run the commands that help in working with IPFS. Some of the prominent IPFS commands are: add, cat, dag, get, etc.

B. Truffle framework

Truffle is a scriptable development environment, testing framework for blockchain using the Ethereum Virtual Machine (EVM). It helps in tasks such as compiling, migrating, testing smart contracts into the blockchain [17].

C. Metamask

MetaMask is a tool available as browser extension and mobile app, which provides the way to connect to blockchain based applications we deployed using truffle. MetaMask provides users with a token wallet, secure login, key vault, and token exchange which helps us manage our digital assets [18].

VII. CONCLUSION

In this paper, we have discussed various aspects related to Indian agriculture, Traceability, Reliability, BlockChain, and Ipfs. The current Indian Agro-Food industry is not well organized under any hood. This is an attempt to put things together in an orderly fashion. The concepts that BlockChain brings to the table adds valuable meaning and organization to this distorted Indian Market and agricultural sector. Using the concepts and ideas learned from the referred papers, we conclude that creating a DApp(Decentralized Application) will solve most of the problems we discussed and create an application which acts as a platform for all the stakeholders in the Agro-Food industry to come together and create a better flow of goods and services to people.

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