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Blockchain Application for Sustainable Supply Chain Management in Indian Agriculture

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***Abstract*— Increasing demand for transparency in agri-food through customer expectation and regulatory imposition has fostered a swift adoption of blockchain technology. Demand for transparency is rising in the agri-food industry driven by consumer expectations and regulatory requirements, which has fast-tracked the adoption of blockchain technology. It creates innovative solutions to augment traceability and combat food deception, while also informing consumers about their origin. Blockchain is by nature trusted and immutable; thus, it is well suited for agri-food stock chains. Considering that the transactions on such supply chains have to be safe and transparent, the existing Smart contract technology based on Ethereum is being improved. Even if updating is difficult and disruptive, the topic of data migration and its users is growing more difficult. This has led most of the agri-food sector migration to Binance Smart Chain (BSC). BSC offers the benefits of confirmation times for transactions, a more efficient consensus mechanism, and thus better scalability. On the latter aspect, use of BSC will eventually ease the updation of smart contracts, thereby upgrading the entire speed and reliability of blockchain solutions for ensuring transparency and traceability in a supply chain.**

Keywords—Binance Smart Chain, agri-food traceability system, smart contracts

I. Introduction

The phrase agri-food encompasses the full food production and distribution cycle, from farming and raising livestock to processing and delivering final goods. Included are activities in the production of primary products such as crops and animals, followed by processing to produce consumable goods. This industry also reaches out into the rather complex process of distributing goods from producers to consumers while keeping safety standards and regulations intact. Consumer demands for transparency and sustainability have accelerated technology innovations like blockchain, which provide traceability and prevent fraud in the supply chain. In this context, the agrifood industry plays a critical role in fulfilling nutritional needs all over the world and continues to evolve by embracing and adopting relevant technologies and practices that help it better react to the challenges fulfill the demand of consumers for transparency and sustainability.

A. Blockchain

Blockchain is the technological system of distribution and decentralization of ledger, fundamentally altering the recording and verification process of information between networked computers. In reality, it is a system of interconnected blocks, each of which holds a list of transactions or data entries. A network of participants, referred to as nodes, is responsible for maintaining this system. The blockchain's transparency and immutability make a difference. Blocks are cryptographically connected to one other after they are added to the chain. This process makes the system completely safe and impenetrable.

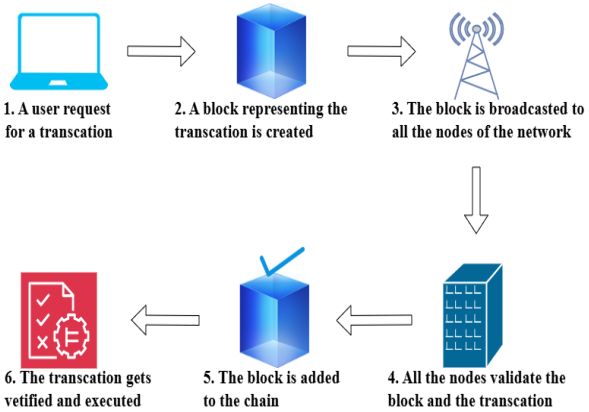

Fig. 1 How blockchain works.

Blockchain technology secures and resists frauds because any transaction is immobile. If any record changes, it will break the chains of all subsequent blocks. Thus, immutability has created trust among the users, which is also amplified by the decentralized nature of the network, making central authority redundant. Transparency and reliability in blockchain increase trust, which is a trustworthy solution for many different types of industries. Although its major application is in cryptocurrencies, this technology is far from financial applications. Blockchain is revolutionizing industries such as supply chain management, healthcare, and others that require transparent and secure data recording and validation. Its versatility highlights its potential to revolutionize processes and enhance operational efficiency globally.

B. IPFS SERVER:

The Interplanetary File System (IPFS) is a decentralized peer-to-peer protocol designed to improve the efficiency and

reliability of hypermedia storage and distribution, compared to conventional centralized servers. This advanced system uses content addresses via cryptographic hashes to distinctively identify files. Therefore, data can be shared across multiple nodes, improving availability even when some resources are offline. IPFS provides protection against suppression and cyber threats, reduces costs, and improves performance. It is used in web hosting, content distribution networks, file sharing, and Decentralized Applications. IPFS has a very different landscape for data sharing and storage that promotes a decentralized Internet; however, it still suffers from the issues of scalability and a wider adoption requirement.

II. Literature Review

A. Blockchain Technology to Support Agri-Food Supply Chains

This paper conducts a literature review for applications in blockchain in the agricultural food industry by synthesizing 183 papers to derive benefits and downsides associated with its application. It supposes that blockchain technology increases visibility for producers and builds consumer trust toward the origin of products. But it also throws out the training gap among the industry stakeholders, the need for the integration of newer technologies like Big Data and Edge Computing, and the lack of supportive tools on the end of the developer. The outcome at the end concludes as potential future research areas to tackle these challenges and bring better blockchain implementation into agri-food supply chains. This paper tracks the key motivators driving the adoption of electronic traceability by the agriculture- food industry and the transmission of value added through such an approach-transparency, accountability, and food safety.

B. Prioritization of e-traceability drivers in the agri-food supply chain

This paper applies hybrid multi-criteria decision-making techniques using FARE and ADAM in a fuzzy environment to determine the critical factors that motivate companies to adopt e-traceability. Findings would thereby identify supply chain efficiency, technology development, and sustainability as the critical drivers for the success of an e-traceability strategy. It does, therefore, hint that a commitment to using technology to guarantee safety and consumer trust is really at the heart of the industry. This paper explores agri-food supply chain management using blockchain technology and groundbreaking ways for superiority and safety improvement in food products. The framework in itself would differ from all previous centralized approaches as it would use a permissioned blockchain such as Hyperledger Fabric to ensure transparency and traceability are guaranteed with integrity of the food products throughout the production chain.

C. Blockchain-Based System for Agri - Food Supply Chain Traceability Management

This paper will introduce a novel approach to improving quality and safety in the food product supply chain via blockchain technology in managing the Agri-Food supply chain. The proposed framework uses permissioned blockchain, Hyperledger Fabric, and does not follow the traditional centralized approach, instead ensuring traceability-based transparency and quality integrity in food production processes. For this, the paper outlines the benefits of a decentralized system: security and immutability of records and participant control, demonstrated through various use cases with a developed prototype. The blockchain solution addresses changing needs within the Agri-Food industry and results in product quality and traceability upgrade for customers. Among these guarantors are consumers' safety and industrial competitiveness.

D. Food traceability system in India

The increasing concern about food safety is coming not only from the consumers' side but also from regulatory levels. Therefore, traceability systems in a food supply chain system are paramount in such cases. A survey concerning traceability in the Indian food industry revealed that though the sector has largely utilized bar codes for pricing, there is an acute lack of awareness of the traces that the need for traceability bears for food safety. Therefore, it calls for an acute requirement to promote education and awareness in the industry on the relevance of traceability systems. Such an elevated level of understanding, therefore, becomes necessary for the fostering of a safety culture, and further, enhances consumer confidence in general and results in the achievement of regulatory standards that help maintain the integrity of the food supply chain in India.

E. Blockchain for Indian Agriculture

This would be vital for increasing awareness in this area as part of efforts toward creating a safety culture, raising consumer confidence, and regulatory compliance to ensure the integrity of the food chain in India. Advances in agricultural technology are paramount to fulfill the pressing need for more food, created by a growing world population. The SDGs will be a vision for the future, and the pace of change is accelerated through technologies like ICT, IoT, robots, drones, big data, and artificial intelligence. In this piece of research, we look at how farming in Budaun, Uttar Pradesh, is changing due to Smart Agriculture. Those who have now integrated blockchain technology have a 20% increase in crop production and a 30% increase in income.

III. Proposed System

The adoption of blockchain technology is growing very fast in the agri-food sector. Increasing demands on consumer levels, as well as on the authorities, to be transparent and legitimize their origin. Blockchain has been applied in several key areas: making sure traceability is secure, counteracts food fraud, and

provides critical information about how food came into being. The inherent property of trustworthiness and impermanence within blockchain technology turns out to be precursors that are taking chain management in the agri-food sector to new heights. However, the complexity and disruption associated with the upgradation of smart contracts on the Ethereum platform have the industry stakeholders looking at alternative options. Among the many alternatives surfacing, there is Binance Smart Chain (BSC). BSC has the strength of having all the issues Ethereum smart contracts' upgrades bring with it. It offers some unique benefits such as faster processing of transaction confirmation times compared to Ethereum, which makes the system work even more efficiently. It makes transaction processing quite fast and responsive, owing to the unique consensus mechanism and shorter block times. The adoption of blockchain in such platforms as BSC for the foreseeable future may provide a promising basis to continue developing demands in this sphere toward smooth and dependable solutions for transparent supply chain management.

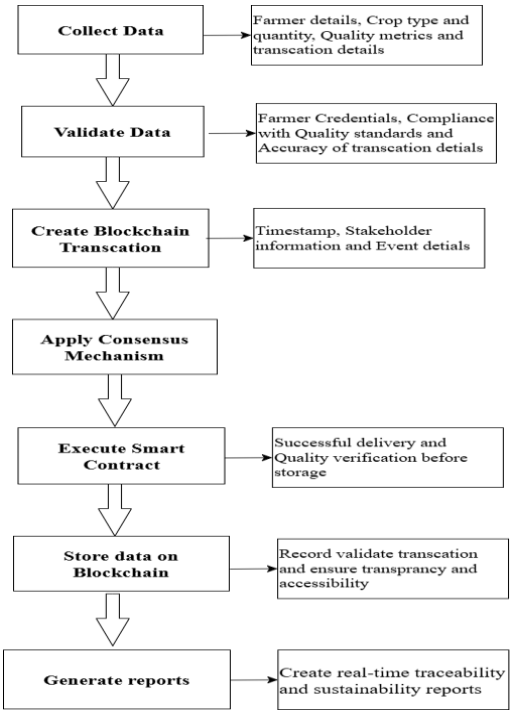

Fig. 2 Flowchart for Proposed system

A. Architecture diagram for the proposed system

This diagram represents a holistic agricultural supply chain that uses the Binance Smart Chain for effective interaction between the different participants, which include Seed Company, Farmer, Grain Elevator, Grain Processor, Distributor, Retailer, and Customer. It begins with the establishment of a farming contract-a formal agreement to obtain seeds and for transparency in agricultural transactions. It is based on the secure and traceable interactions among the different stakeholders. With these seeds, the farmer proceeds to grow the crops, maintaining records of important information regarding planting techniques, growth cycle stages, and resource allocation. All this information is consistently uploaded into the InterPlanetary File System (IPFS) for decentralized storage, assuring no tampering with the records. Once harvested, the products are then sold to the grain elevator for further recording of information concerning storage conditions, quality appraisal, and inventory levels. This integration of Binance Smart Chain and IPFS allows for real-time updates, thereby tracing the supply chain in a transparent manner. The system not only facilitates the movement of agricultural products from farm to consumer but also empowers stakeholders with reliable data. It increases trust, accountability, and efficiency in the agricultural supply chain.

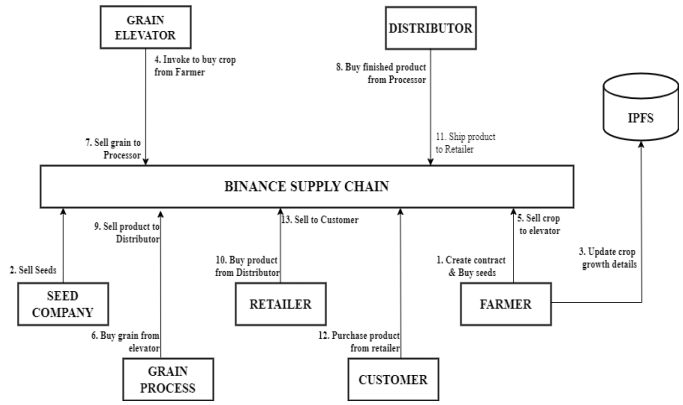

Fig. 3 Architecture Diagram

This decentralized storage system ensures that critical information about the conditions of crops is accessible and not able to be changed, therefore all parties maintain transparency throughout the supply chain. At each point of the grain's processing, distribution, and retail, every transaction is carefully recorded on the blockchain. Blockchain integration ensures traceability so that participants are able to see in real-time where the agricultural products have been as well as the status. It records every transaction, hence heightening the transparency and creating that element of trust among the stakeholders, from the producer up to the consumer. That is a very good account of integrity in agri-food industries, mainly because consumers will be demanding guarantees on the quality and origin of foodstuffs in vast numbers today. Therefore, all such integration through blockchain technology streamlines activities but also reinforces the integrity and trustworthiness of agricultural product supply.

IV. Modules Used

A. Seed Company Module

The seed company module is a module that represents the entities offering seeds to the farmers. Utilizing blockchain technology enables the generating of digital contracts for seed

sales. The seed company will ensure that quality seeds verified on the blockchain are provided to the farmer, thus creating a platform for successful farming. All these transactions will be recorded in the blockchain, which carries a transparent history of seed origins.

B. Farmer Module

The Farmer module is the heart of an agricultural supply chain. The Farmer has activities on planting and harvesting crops. After purchasing seeds from the Seed Company, the farmer logs data regarding growth in the InterPlanetary File System (IPFS). This way, all the farming activities involved become traceable in real time. This module increases the traceability of a product because all the actions of a farmer can be tracked along the supply chain.

C. Grain Elevator Module

The grains are sold to Grain Elevator, which acts as a storage and initial processing point once harvested. This module will record purchase transactions from the farmers and track inventory levels on the blockchain. The Grain Elevator plays a great role in the organization of grain storage's logistic services, thus detailing records of incoming and outgoing products.

D. Grain Processor Module

The Grain Processor unit takes raw grains from the elevator and has them processed into market-ready products. The unit records the processing steps, quality control measures, and safety standards into the blockchain whereby consumers will receive safe and high-quality foodstuffs. The documentation of processing activities improves accountability along the supply chain.

E. Distributor Module

This module oversees the logistics associated with processing grains and ensuring their delivery to retail stores. Here, a distributor acquires shipping information and monitors the movements of goods originating from a processing plant to a retailer. Updating the blockchain with all shipping status and logistics details this module ensures that the distribution process is more transparent and reliable.

F. Retailer Module

The Retailer module is the business module that sells its product directly to the consumer. It holds all the records of products in stock, sales transactions, and customer interactions. With the aid of blockchains, it enables the retailer to provide consumers with information about origin and quality, which would increase trust and enable them to make suitable purchasing decisions.

G. Customer Module

The customer module, which comprises all the end consumers of the farm produce. Customers will see the entire track of the product and hence will know exactly where their products came from and of what quality. The trust factor in the agricultural supply chain will be enhanced by this module since consumers can make well-informed decisions through correct information about the products.

V. RESULT AND DISCUSSION

Proof of Stake and Proof of Authority are two of the most basic consensus mechanisms used in blockchain networks. In the Proof of Stake approach, validators are selected based on the magnitude of their stake; this is the amount of cryptocurrency locked within the network to encourage responsible behavior. On the other hand, Proof of Authority is based on pre-existing reputation or authority of validators, and this may create a degree of centralization since the attributes are mostly predetermined. Another approach known as PoSA, or Proof of Stake and Authority, combines both by choosing validators according to their historical performance and thereby increases the strength of reputation and provides a balance between decentralization and robust conviction.

The PoSA framework, validators holding bigger stakes with a strong reputational reputation are selected more so to be involved in a block's validation. More importantly, this helps ensure efficiency and enhanced security for the whole system: The stake of every single validator set by stakeholders; at times including reputation scores attached to these validators' holdings, gives them higher or less chance to be picked on selection.

A. Stake

The stake represents the amount of cryptocurrency a validator lock within a network has to stake in order to be included in the consensus process; thus, it represents both a financial commitment and a means of incentive for honest behavior. In PoSA, which is a hybrid of both Proof of Stake (PoS) and Proof of Authority (PoA), the size of the stake directly affects the chances of a validator being chosen to validate transactions and generate blocks. Validators with more stake have more trust and investment in the network. PoSA is staking combined with identity-based accountability, ensuring decentralization, scalability, and security while aligning economic incentives with network integrity and reliability.

$$S_i = \sum_{k=1}^{n} C_k$$

Where:

- S_i is the total stake of validator i,

- C_k is the contribution of each participant staking their coins with validator *i,*
- n is the number of participants staking with the validator.

B. Validator Selection Probability

The blockchain networks using Proof of Staked Authority, the probability that a validator will be elected to make the next block proposal is dependent on a weighted valuation of both the stake made by the validator and reputation. The stake represents the cryptocurrency amount a validator has put into the network, and its reputation reflects the validator's history of dependability and trustworthiness. Validators with greater stakes and sturdier reputations have a greater predisposition toward selection. Hence, a vested interest in the proper functioning of the network, guarantees that the functioning of consensus remains sound and equitable with efficiency in being economically aligned with the behaviors inculcated regarding the integrity of the same network.

$$P_i = \frac{S_i \times R_i}{\sum_{j=1}^{m} S_j \times R_j}$$

Where:

- P_i is the probability of validator i being selected.
- S_i is the stake of validator *i,*
- R_i is the reputation score of validator *i,*
- m is the total number of validators.
- $\sum_{j=1}^{m} S_j \times R_j$ is the sum of all validators stake and reputation products.

C. Block Reward

In Proof of Staked Authority (PoSA), a proposer who gets their proposed block added to the blockchain gets rewarded most of the time in new coins minted or part of transaction fees. These incentives give the validators immense strength, keeping them honest and efficient. The way PoSA ensures that its financial rewards go in tandem with the integrity of the network is in line with what is called best for the blockchain. The reward mechanism not only fosters active participation but also enhances the security and reliability of the network, fostering self-sustaining ecosystem operation where validators are driven by the urge to respect the rules of the protocol for it to operate smoothly.

$$B = \sum_{i=1}^{n} T_i + R$$

Where:

- T_i is the transaction fee for each transaction in the block,
- R is the base block reward set by the network.

D. Voting Power

In Proof of Staked Authority, validators have voting rights therefore, they can partake in the governance of the network. This usually is proportionate to the stake and performance history inside the network. Validators having larger stakes and a good history of contribution have greater influence in the decision-making processes such as protocol upgrade, policy change, or dispute resolution. Thus, it guarantees that an entity holding a significant investment or commitment to the network can have an important position on its development and governance. In this way, the Proof of Staked Authority (PoSA) advocates fair, accountable, and decentralized distribution by aligning the stakeholder's voting power in relation to performance.

$$V_i = \frac{S_i}{\sum_{j=1}^{m} S_j}$$

Where:

- V_i is the voting power of validator i,
- S_i is the stake of validator i,
- $\sum_{j=1}^{m} S_j$ is the sum of stakes of all validators.

E. Comparison of POS And POSA

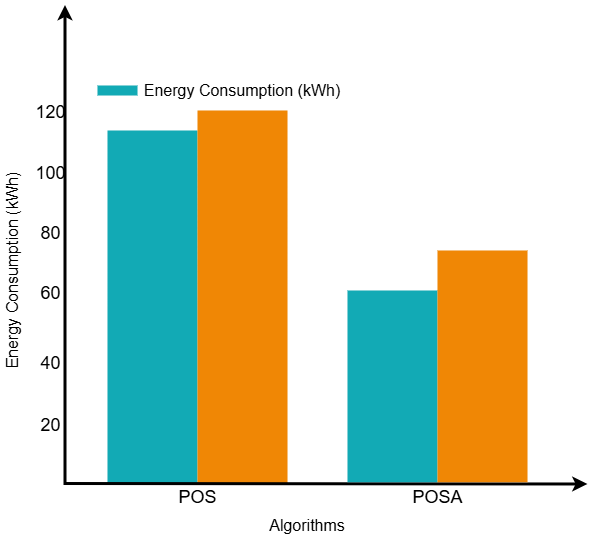

Fig. 4 Comparison of POS and POSA Algorithm

Due to optimized resource utilization, the POSA would require less energy and also take less time to execute than the normal POS algorithm because it would require less computation to validate transactions. Besides this, POSA provides more efficient consensus and facilitates faster processing of transactions and block validation, which ultimately means that execution times are reduced. In general, all these enhance the sustainability and efficiency of using POSA in blockchain systems.

VI. Conclusion

In conclusion, the agri-food industry heeded the call for increasing transparency through a wide diffusion of blockchain technology in commercial applications. Notorious for their inherent trustworthiness and immutability, blockchain technologies have even overcome significant issues in supply chain management. Although Ethereum has played a great role, complexities related to the upgrade of smart contracts have led to an extensive exploration of alternatives that promise very much with the Binance Smart Chain (BSC). Therefore, the overall faster transaction times with the efficient mechanism of consensus negate the efficiency issues that are witnessed with Ethereum, and BSC proves to be a soundly reliable platform for the transparent management of supply chains. The architecture diagram shows how blockchain technology changes the agri-food industry by enhancing traceability, security, and transparency in the supply chain. With blockchain integration, stakeholders can enjoy real-time tracking, tamper-proof transaction records, and unified connotation. Key features such as decentralized ledgers and smart contracts provide safety to data, reduce fraud risks, and automate processes such as payments and quality checks. This enhances efficiency and establishes trust and accountability between the farmers, distributors, retailers, and consumers. Blockchain adoption is reshaping traditional supply chain management into a more transparent and consumer-centric system. It gives accurate information regarding the products consumed by consumers is consistent with standards of regulation and promotes sustainable operations through minimum waste. Blockchain technology makes agriculture more efficient and gives it an intelligent, resilient system in quality, safety, and sustainability for future success.

References

[1] Marco Fiore, Marina Mongiello. "*Blockchain Technology to Support Agri-Food Supply Chains: A Comprehensive Review"*. ACCESS.2023.3296849.

[2] Mladen Krstic, Giulio Paolo Agnusdei , Sne´ zana, Paolo Miglietta.ˇ "*Prioritization of e-traceability drivers in the agri-food supply chains*". (2023) 11:42.

[3] Angelo Marchese, Orazio Tomarchio. "*A Blockchain-Based System for Agri-Food Supply Chain Traceability Management*". (2022) 3: 279.

[4] Eram S Rao, Seema Shukla, Rizwana. "*Food traceability system in India*". (2022).

[5] Mehtab Alam, Dr. Ihtiram Raza Khan. "*Blockchain for Indian Agriculture: A Revolution*". Vol. 9, No.2, 2021.

[6] Coco L, Mannaro K, Tonelli R, et al. "*A blockchain-based traceability system in agri-food sme: case study of a traditional bakery*". IEEE Access,2021;9:62,89962,915.

[7] Baralla G, Pinna A, Tonelli R, et al. "*Ensuring transparency and traceability of food local products: A blockchain application to a smart tourism region. Concurrency and Computation: Practice and Experience*", 2021;33(1).

[8] Antonucci F, Figorilli S, Costa C, et al. "*A review on blockchain applications in the agri-food sector. J Sci Food Agriculture*". 2019;99(14):6129–38.

[9] Casino F, Kanakaris V, Dasaklis T, et al. "*Modeling food supply chain traceability based on blockchain technology*". IFAC-PapersOnLine. 2019;52:2728–33.

[10] Androulaki E, Barger A, Bortnikov V, et al. "*Hyperledger fabric: A distributed operating system for permissioned blockchains*". In: Proceedings of the Thirteenth EuroSys Conference, EuroSys '18, 2018.

[11] Caro MP, Ali MS, Vecchio M, et al. "*Blockchain-based traceability in agri-food supply chain management: a practical implementation*". 2018.

[12] Biswas K, Muthukkumarasamy V, Lum W. "*Blockchain based wine supply chain traceability system*". In: Future Technologies Conference (FTC 2017), 2017; 56–62.

[13] Chen K, xin WANG X, ying SONG H,. "*Food safety regulatory systems in europe and china: A study of how co-regulation can improve regulatory effectiveness*". J Integrative Agriculture. 2015;14(11):220317.

[14] Dabbene F, Gay P, Tortia C. "*Traceability issues in food supply chain management: a review*". Biosyst Eng.2014;120:6580.

[15] Bosona T, Gebresenbet G. "*Food traceability as an integral part of logistics management in food and agricultural supply chain*". Food Control. 2013;33(1):3248.