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Leveraging Blockchain, IoT and Edge Computing for sustainable Agro Food Supply Chain in Smart Cities

Smart Edge: IoT and Blockchain-based Cognitive Edge Computing for Sustainable Smart City

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***Abstract*— The real time augmentation of technology is rapidly exploding in various aspects of our daily life and these technological breakthrough have paved the way for smarter lifestyles and thus smart cities. However, inspite of various technological advancements, the agriculture and farmer community are still facing some of the greatest problems related to the food supply chain. Thus, the farming and agriculture industry can embrace the cutting edge and industry 5.0 technologies like Blockchain, IoT and Edge Computing to address the issues of food supply chain by providing digital connectivity and transparency. The supply chains are evolving into automated and highly complex networks and are becoming an important source of potential benefits in the agro industry. At the same time, consumers are now more interested in food product quality. However, it is challenging to track the provenance of data and maintain its traceability (quality and cost) throughout the supply chain network. The traditional supply chains are centralized and they depend on a third party for trading. These centralized systems lack in transparency, accountability and auditability and thus lead to serious problems such as fraud, tampering and man-in-the-middle attack. Also, the traditional centralized storage schemes are unable to handle large amount of data produced during supply chain processes and consequently cause bottlenecks. So, there is a need for a reliable system that ensures traceability, trust and delivery mechanism in the Agri-Food supply chain preserving the credibility of the involved entities, accountability of the trading process and traceability of the products. The proposed solution, presents a complete solution for Blockchain, IoT and Edge computing based Agriculture and Food (Agri-Food) supply chain. It leverages the key features of smart contracts and IoT deployed over a distributed network. Edge computing is used to lower the cost of data processing, increase the average response time and also provide real-time visibility and management of the supply chain.**

***Keywords*— *Agri food supply chain, smart cities, Blockchain , distributed environment, IoT, Edge Computing*.**

I. INTRODUCTION

A blockchain is digitalized and distributed spreadsheet whose objective is to record all the transactions. Also, blockchain technology tracks tangible and intangible assets. Blockchain is an immutable digital distributed ledger technology eventually an eminent gamechanger in the world. The transactions are replicated and administered across a peer-to-peer network, in such a way that makes it challenging or infeasible to alter, fraud, or hack the system. Practically anything of value can be tracked and traded on the blockchain network, minimizing the risk and cutting costs for all the participants involved. It can unite a distinct group of people who have not precisely authorized reliable relationships with one another by providing transparency and tamper-resistance essence. Each block in the chain consists of numerous transactions, and every time a new transaction appears, a record of that transaction is added to every participant's ledger, reducing the need for intermediaries. These records of transactions could help supervise every aspect of proceedings providently.

II. HOW DOES BLOCKCHAIN WORK?

In a business, assets are dispersed worldwide, a single person cannot manage, track and keep a record of all the transactions. When an authorized participant uploads a transaction, the system runs complex algorithms to check whether the transactions are valid or not.

Blockchain technology is an organized structure that deposits every transactional record which is known as "block", in the distinct database which is known as "chain" across the network connected through peer-to-peer nodes. Eventually, this repository is indicated as a "digital ledger". The data stored in a block is relied upon and linked to the data in a previous block and over time, it forms a chain of transactions consequently leading to the formation of blockchain. This process continues each time a new transaction of data takes place. The decentralized database driven by multiple participants over a network is known as Distributed Ledger, this feature provides equal access to the data to all the authorized participants in the network.

Each chain abides several blocks and each block consists of transactional data, randomly generated 32-bit whole number called as the nonce, followed by a 256-bit number block header called as the hash. Each block has its unique nonce and hash and also refers to the hash of the previous

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block, which makes it difficult for mining a block for an unauthorized participant.

Several nodes implement a variety of algorithms for analyzing the authentication of each transaction. If the transactions are authentic, then it is accepted in the ledger and the block is added to the existing chain.

On the other hand, if a transaction is found unauthentic, it is not added to the blockchain. This is how blockchain technology works.

III. EASE OF USING BLOCKCHAIN

A. Traceability

No records can be lost replaced or destroyed. A blockchain-based system eliminates the risk of documents or products being stolen through fake identifiers, which increases traceability and security.

B. Clarity

Safe and transparent transactions build trust among all participants and minimize manual work and no delays in paperwork. One of the advantages of using smart contracts (self-executing contracts with the terms of deals written as a simplified program), all the agreement conditions can be executed automatically, without any human intervention.

C. Fault Finder

The data collected in a blockchain is not vulnerable to inaccuracy, bugs, and hacking. Blockchain helps to identify the culprit. It prevents fraud if the data collected has no error.

D. Accelerate Transactions

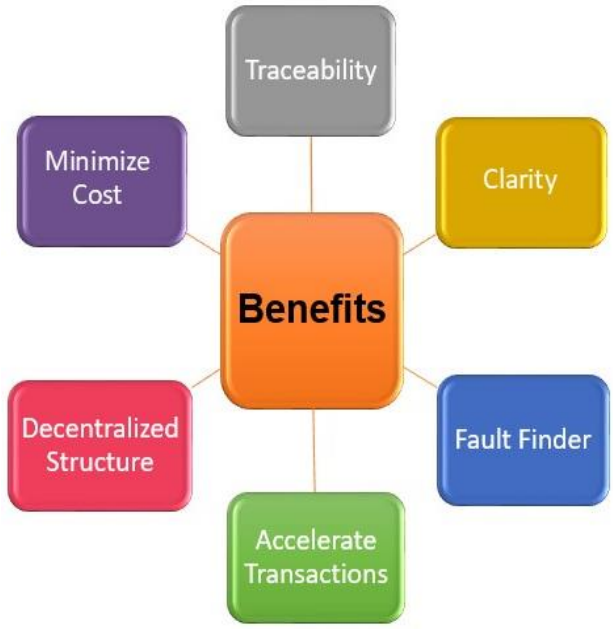
Blockchain enables the speed payment process. Moreover, the importance is in assisting farmers because blockchain guarantees more value and better selling chances to consumers directly eliminating middlemen.

E. Decentralized Structure

Blockchain allows each authorized participant in the system to have a copy of the exact data in a distributed ledger. Decentralization indicates the transfer of control and decision-making from a centralized entity like an individual, group, or organization to a distributed system.

F. Minimize Cost

The blockchain feature can minimize costs for organizations. This increases efficiency in processing transactions. It reduces manual tasks and simplifies auditing processes. It helps organizations by eliminating middlemen.



IV. PROBLEMS IN ENDURING FOOD SUPPLY CHAIN

Food shortages, imbalance in demand of products, small landholdings, increase in cost, pre-/post-harvest losses, rise in demand of consumers for safe and quality foods, nutritional security, access to market information for farmers, exposure to global opportunities for free trading or technology transfer, lack of updated information, unorganized and inadequate market infrastructure in agro-food supply chains.

A. Lack of traceability

Lack of traceability and transparency may create blind spots in the agro-food supply chain and lead to unnecessary risk. It can break consumers' trust which leads to lower sales and profits. It can give rise to legal issues as well.

B. Inability to maintain the safety and quality of products

It is tough for manufacturers to produce and deliver high-quality products. Storing the products in the warehouse is burdensome. In supply chain management products are delivered mainly based on customers' requirements with the right quality and quantity. Delay in transportation affects the supply chain.

C. Inadequate communication between parties

Lack of communication among the participants can create a major impact on the food supply chain. This is because there are various parties involved in the supply chain having less knowledge. Poor communication causes inefficiency and can lead to mistrust among suppliers and their consumers.

D. Rising supply chain costs

Across the globe suppliers, manufacturers, logistics, and consumers are spread widely which requires deliberate tracking and coordination to complete the process, and to supply them on schedule requires manpower, fuel, and investment in new technology which increases the cost. Frequent changes in the consumer's requirements cause major issues in risk and cost management.

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E. Failure to track and control inventory in warehouses and stores Rising supply chain costs

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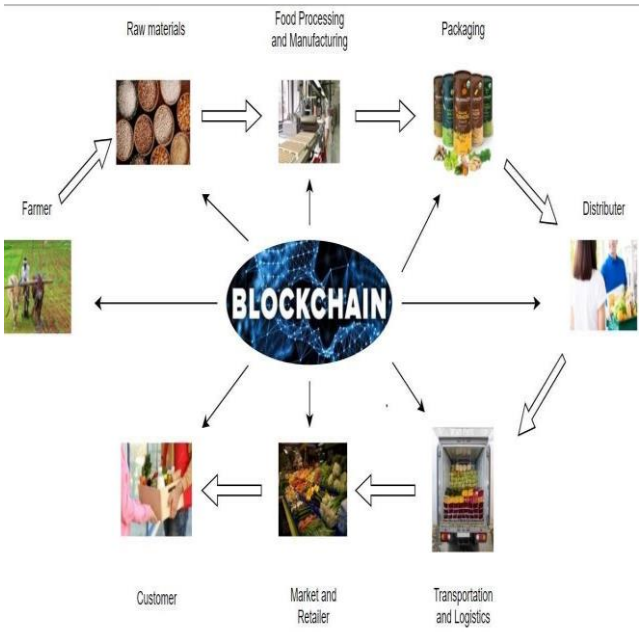
F. Failure to track and control inventory in warehouses and stores

One of the major issues that occur is with the inventory. To minimize costs, maintain quality, and satisfy consumers, is difficult. If the quantity is more it will spoil or if quantity is fewer, then consumers will be disappointed. There is a definite trade-off in keeping consumers happy and reducing waste.

V. CONVENIENCE OF USING BLOCKCHAIN TECHNOLOGY IN FOOD SUPPLY CHAIN

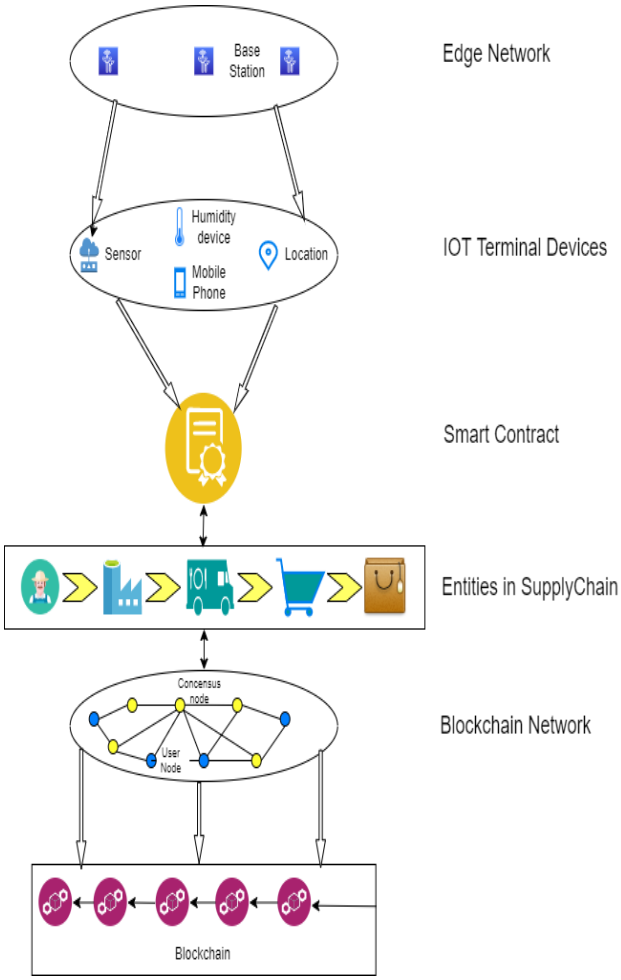
Blockchain technology enables the traceability of information in the agro-food supply chain and ensures food safety. It facilitates a secure way of storing and managing data, which provides the development and use of data-driven innovations for smart farming.



VI. WHAT IS A SUPPLY CHAIN?

The supply chain is a process of administrating the integrated production flow of products or services, ranging from the raw materials to delivering the ultimate product to the consumer. Every product that reaches an end-consumer represents the collective effort of many organizations and stakeholders. Supply chain management involves the coordination among the members for a control flow of supply of goods. Supply chain management involves a large number of entities like farmers, processors, distributors, retailers, consumers to carry out the entire process of transportation and production from origin to the end-users. Due to the involvement of more number of entities, it is inconvenient to trace and track the entire process. One of the major issues faced by a farmer is due to the presence of intermediates in the supply chain system. Due to the lack of a price fixation system of the agricultural products, farmers are demanded to sell their crops to middlemen at a lower cost. But middlemen have predominance in determining prices and selling the crop to consumers at a higher cost. So, neither the farmers can get reasonable prices for their products, nor the consumers can get the products at an economical price. It is a huge loss for farmers as well as consumers, but middlemen are making a huge profit, because of which the agricultural market has been seriously affected by the middlemen. This problem can be overcome by using blockchain technology in the supply chain and eliminating middlemen.

VII. INTEGRATING BLOCKCHAIN, IOT, EDGE COMPUTING IN SUPPLY CHAIN



A. Blockchain in Supply Chain

Blockchain is an innovative solution for a wide variety of problems in the agro-food supply chain. Integrating blockchain improves the efficiency of the global supply chain system. Blockchain is a promising technology that has the

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potential to enhance traceability, transparency, quality, safety, security, build trust, reduce risk, eliminate middlemen, and minimize cost. Blockchain technology allows authorized entities to perform transactions directly without the involvement of a third party. It is a decentralized, distributed ledger that records all the transactions in real-time and is immutable, which provides security. It provides access to all the transactions among the authorized entities at the same time, this shared infrastructure of the blockchain provides transparency among the participants. Every single transaction is in the form of a timestamped block, and these transactions have to be approved by a majority of the participants in the network before performing any further activity which provides traceability. This can be achieved by introducing smart contracts.

The organization may use blockchain technology to more safely and transparently track all types of transactions. The supply chain function could be severely impacted. Companies can use blockchain to track the history of a product from its inception to its current location. Every time a product changes hands, the transaction is securely recorded, producing a permanent record from the point of manufacture to the point of sale. Parties collaborating on a single shared platform could use this sophisticated technology to drastically decrease transaction time delays, expenses, and human error. Fraud risks are reduced when there are fewer intermediaries in the supply chain. Finally, comprehensive records help businesses locate the source of fraud when it occurs. Within a supply chain, a shared blockchain ledger provides a reliable and tamperproof audit trail of the flow of information, inventory, and finance. Companies can synchronize logistical data, track shipments using a common blockchain.

Smart contracts are legal in the form of digital agreements among the participants within the network, these smart contracts are simple programs stored on the blockchain and are self-executed when predetermined conditions are met, which reduces the complexity and eliminates fraud in the supply chain by automating the execution of the agreement and verifying multiple transactions among the participants. Only the authorized participants can view the outcome by eliminating the middlemen. This feature automates the workflow and triggers the subsequent action to be performed when the predetermined conditions are satisfied. The data to the block is added once the transaction is completed. And then this block of data is updated to the blockchain.

B. IoT in Supply Chain

The Internet of Things (IoT) is a linked network of physical objects that can monitor, report, communicate and exchange data. Location, temperature, humidity, light levels, mobility, handling, speed of movement, and other environmental parameters are all measured by sensors in IoT devices. When used in the global supply chain, IoT technology may help organizations provide better service to their consumers while also saving money and increasing overall efficiency.

Implementing IoT technology in blockchain based agro-food supply chain systems facilitates tracking the whole life cycle of products by organizations and consumers. IoT includes connecting physical devices such as sensors and other smart technologies to gather heterogeneous data from various system and communicate it to the authorized participants without the involvement of a third party. The deployment of IoT devices across the supply chain, from manufacturing to transportation and distribution centers, provides visibility and data collecting. Connecting these devices to IoT device management solutions centralizes visibility and provides real-time insights where they are most required. Accurate data is collected automatically by IoT devices and stored on the blockchain. Integrating blockchain and IoT together speed up the movement of products and ensure delivery on schedule time resulting in saving time.

IoT devices can be connected to individual storage containers, as well as raw materials or finished goods. The IoT sensor will send its location to GPS satellites, which can then be used to track the movement of products. It is considerably easier to forecast how things will move through the supply chain when the speed of movement and traffic flow of products are tracked. Suppliers, manufacturers, and distribution centers may plan ahead of time to receive items, reducing handling delays and ensuring effective material processing. Organizations can monitor the safety and storage condition of the products across the supply chain and decrease spoilage. If specific thresholds are crossed, these devices may trigger an alarm. This makes it much easier to monitor product quality. IoT sensors can be accustomed to manage and identify the accurate location of products stored in a large warehouse.

C. Edge Computing in Supply Chain

The main objective to impose Edge Computing in our proposed methodology is to cope with the challenges faced in the agro-food supply chain because of the rise and increasing computation power of IoT devices. Edge Computing enables the cloud to be distributed closer to its users, by moving the cloud closer to the devices which are located far from the cloud. It accelerates larger computational processes, reduces the likelihood of security incidents, saves time and money, and provides organizations with real-time data insights by reducing distance and data movement.

Latency is a problem that all supply chains must deal with. To establish a fast and efficient supply chain, it is critical to shorten the time between requesting data and the commencement of transmission, and edge computing can help to achieve it. Latency can appear in a number of ways, often due to security risks and line failures that can significantly slow down supply chain operations. Fortunately, edge computing can also reduce them. In terms of security risks, since edge computation tasks can run in multiple systems concurrently, an attacker would have to attack them all at once for a significant breach to occur. In addition, applications are designed to be completely redundant, which means that all data must be validated before entering the

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database system of records. As a result, the possibility of transmission errors is also significantly reduced.

Generally, the larger the supply chain, the harder it is to monitor and manage. Over the years, supply chain technology has limited the information that can be provided, reduced transparency, and made it more difficult to manage. In a supply chain system, organizations can make use of edge computing to monitor the defect of the merchandise and can improve the quality. Enterprises can also automate time-sensitive supply chain processes. These automated processes can predict, simulate, and optimize results, reducing the need for centralized management and reducing human decision inefficiencies. Edge computing provides high bandwidth, minimum latency, and accessibility. It is essential to minimize the lag in requesting and capturing data to accelerate the supply chain, as there is an increase in the number of IoT devices and the enormous volume of data generated rapidly. Edge computing provides a simplified end-to-end model. Transmitting all the information captured by IoT devices to a centralized data store such as the cloud may cause latency and bandwidth issues, to overcome these challenges and for efficient processing of data, edge computing can be used. Instead of sending data to a centralized data storage, processing and analysis of data can be performed at the source where actual data is generated, and the outcome of computing can be transmitted to the central data storage for review, which reduces processing and response time. Network optimization can be achieved by measuring the number of users across the network and each user traffic to determine reliability. Integrating blockchain and edge computing ensures scalability and security.

CONCLUSION

The combination of Blockchain, IoT and edge computing can significantly address key issues of the global supply chain and add value to the organization. Most of the critical concerns in the agro-food supply chain like security, time reliability, and scalability are addressed, and also provides a trustworthy service to all the authorized participants in the agro-food supply chain. The proposed methodology eliminates data leakage, fraud, and malicious data usage. Smart framing based on blockchain will be an alternative in the agricultural sector in the near future. This would not only improve the quality of food at a low cost, but also it will drive the agro-economy of the country. However, the greatest challenge is the initial cost of computation and sensor installation is high, but in the long haul, it will be a better way of farming both in terms of quality and profit. This would improve the economy of a nation.

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