Role of Internet of Things (IoT) with Blockchain Technology for the Development of Smart Farming

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Abstract

Agriculture and its supply chain is one of the major domains of research which need attention for its growth in all developing countries. Food safety and its supply are also drawing the world attention towards its importance and people are focusing on it because of health hazards. In this research, we have presented a model for the uplift of traditional agriculture field to smart farming, considering blockchain with IoT technology. This system promises to provide equal opportunity to all stakeholders involved in the agricultural food supply chain; even they are not interconnected. IoT devices are added to the smart model to reduce human interference for data collection, recording and verification. The validation of our novel model is compared with our own scheme utilizing only IoT devices deployed in the monitoring field without block-chain.

Keywords: Agriculture, Blockchain, Novel, IoT, Smart Model

I. Introduction

The governments have always been concerned about the quality of the agricultural product. Understanding and optimization of existing agricultural food tracking systems can decrease the presence of polluted and poor goods. A present solution is to record the product information manually, save it to a specific database, and provide customers with a visual query interface [VI]. But, in implementing this system, there are two problems that are difficult to solve. On one hand, the data is recorded by human beings, and it is difficult to guarantee its authenticity, so the credibility is low. On the other hand, the data is stored in a centralized data center that is easy to tamper with and difficult to monitor [XI] The above problems can be solved to some extent by combining Internet of thing technology (IoT) and blockchain
technology (BCT). The IoT can make the devices smart and carried out automatic transmission and measurement instead of manual, the use of IoT devices not only keep back labor cost but also improve data reliability [XXIII]. The BCT has distributed ledger technology with tremendous features like decentralization, confidentiality, safety, and fairness. The use of blockchain technology, data tampering can be prevented to some extent and system can be more confident [XXIV].

This paper proposes a blockchain and IoT based agricultural product tracking system to track the entire process of agricultural product lifespan which can greatly enhance the consumer confidence in the food and improve the functioning of brand protection. An optimized solution to these problems is suggested in two different situations primarily to provide security to the data of the companies involved in the agricultural food supply chain with the help of blockchain. Secondly, IoT technology is added to the blockchain so that complete product lifecycle may be monitored to avoid the risk of poor quality and expiry of food. Research studies have proven that IoT systems provide effective solutions to a variety of problems related to agriculture and in our case blockchain with collaboration of IoT will open a new corridor for agricultural food supply chain where all stakeholders (farmer, supplier, distributor, retailer, and consumer) will make transparent transactions and trustworthy environment will be created for them without the help of mediators.

I.i. Agriculture

Agriculture is an important sector of the world economy and a strong foundation for human life it is the largest source of food grains and other raw materials. Agriculture plays a dynamic role in the growth of country’s economy. It is the main source of income and very helpful for the development of the economic condition of the country, the growth of the agricultural sector is very important [I]. Unluckily farmers still far away from modern technologies and still relying on the traditional methods of farming and food supply techniques which results low productivity and countries are producing yields much below their potential [XVI]. To overcome these problems and bring revolution in the agriculture sector, modern technologies can play a vital role and can resolve these problems [XXV].
I.ii. Technologies used in agriculture

Figure 1: Technologies presently using in agriculture

I.ii.a. Internet of Things (IoT) Technology

To connect objects with a network for information exchange and communication IoT technology is used. IoT is capable to make billions of interconnected devices that are also termed smart objects. These smart objects are proficient to collect environmental information and communicate with other systems through the internet [XVIII]. IoT based applications are developed which enabled devices for monitoring and control in a different domain including process, home appliances, health monitoring applications, smart home, smart cities, smart agriculture, etc [V].

IoT applications have unique importance throughout the lifespan of the agriculture sector, such as cultivate yields, irrigation, harvesting and post-harvesting, crop storage, processing, transportation, and sales. For agriculture applications there are a variety of specialized sensors are available, for instance, soil moisture sensor, humidity, Leaf moisture, solar emissions, Infrared radiations, Rain predictor, etc. In the scenario of IoT, sensors can be installed in different fields like greenhouses, seed storages, cold storages, agriculture machinery, transportation system, and livestock; and their data can be stored in the cloud for monitoring and control shown as figure 2[XXIV].
I.ii.b. Wireless Sensor Networks (WSNs)

For sensing and analyzing the various different parameters that are required in the agriculture domain, WSN technologies are available. To utilize sensors in agriculture many applications have been developed. Sensor networks are the best options to make a strong bond between cyberspace and the real world, by design sensors, are much appropriate to connect agriculture to the IoT. WSN are cheap devices and capable to work in specific environments and work for a long period without battery replacement [XVII].

I.ii.c. Cloud Computing (CC)

Cloud computing is the provision of computer or IT infrastructure through the use of the internet that is providing share resources at cheap cost. The service provider (SP) offers different services and platforms on low cost to store and share agricultural data through used cloud computing [XXVI].

I.ii.d Big-data

The big-data is referred to a huge quantity of data gathered from the different channels for extended periods of time like data collected from sensors, social networking, and business data is called big-data. The big-data have many challenges like capturing, storage; investigation and research. To cut the production cost big data is useful in the agriculture domain for maintaining supply chain management of agricultural products [VIII].

I.ii.e Mobile Computing

Mobile computing has low information sharing cost and easily available and widely being used in different sectors including agriculture. Mobile computing-based systems are being used for sending time to time sessional update to farmers about farming to make timely decisions [XXII].

I.ii.f RFID Technology

RFID Technology in Agriculture. Radio frequency identification, or RFID, has been widely used in livestock to identify animals. But global futurist says use of the tagging technology will expand to crops as the technology gets exponentially better, faster and cheaper. Application of RFID is used agriculture for food traceability, livestock, precision farming and cold chain experiences as shown in figure 3 [XXIII].
I.iii. Agricultural Food Supply Chain

In a food supply chain, a network of stakeholders (Input supplier, Food producer, Food processor, Food distributor and consumer) make transactions with each other in the form of growing, processing or selling food to the end customer and makes sure that the right quantity and the quality product reaches the right destination at the right time shown as figure 4 [IV].

I.iii.a. Technology used in agricultural food supply chain

Food supply the chain has attracted several important and advanced technologies for its process like artificial intelligence, advanced analytics, Internet of Thing (IoT), autonomous mobile reboots and autonomous vehicle, Virtual personal assistants, (VPAs) [VII], Robotic process automation (RPAs), Electronic Data...
Interchange (EDI), Collaborative Planning Forecasting and Replenishment (CPFR). Through the use of these technologies, paperwork has been reduced, product traceability has been improved and bull-whips effect in the food supply chain has also been controlled [IX]. Related research studies have proven that technology can improve product documentation, food quality, food safety, wrapping and software development [X]. Mostly product documentation is made on paper, bar codes, RFID tags, and electronic systems. Adoption of technology can also attract consumers to buy more goods [XIV]. Amazon has adopted the latest technologies such as camera, sensors and sophisticated AI software to charge the customers thru their amazon app on their smartphone [XXVII]. To improve the supply planning and overall logistic operations an IT-enabled food tracking system was also proposed in [XXVII].

The existing technology that has been mostly used in today’s food chain is a centralized database that gathers data about product features only once it dispersed to the distributor and then to the seller. It is mainly appropriate in a centralized retail supply chain where the sellers own their distribution system and logistics. Information about the product in upstream phases from processor till the farm is kept as database silos in the form of excel sheets and hard copies [IX]. For the transformation of the existing technique of data collection, data distribution and data safety it is necessary to make an end-to-end tracking system based on information technology system or an on blockchain technology [XV].

I.iv. Blockchain Technology

The power of Bitcoin improved significantly all over the world and China produced two-thirds of those Bitcoins with blockchain technology. According to blockchain experts, it revolutionizes our daily life. A blockchain is a decentralized ledger that was primarily proposed to record the cryptocurrency transactions that occur inside a digital currency system. Cryptography and blockchain is the spine technology behind the first decentralized digital currency developed by Satoshi Nakamoto in 2009 denoted as Bitcoin [XVIII].

The general opinion about the blockchain is that was made for the currency only. However, it can be useful to other zones by applying a decentralized operational system. Based on this background we decided to utilize its potentials in the agricultural food supply chain [XV].

Blockchain is an emerging technology and presently getting the attention of many industries like finance, healthcare, Education, Food and the management sectors. The main reason that blockchain is getting attention is its unique features that operated only by a trusted intermediary in a decentralized method, without the help of authentication system and capable to achieve the same goal with the same
Blockchain opened the new pathways and introduced trustless networks because with the blockchain you can make a transaction without trust on other parties. The function of mediators has eliminated and transactions have become faster between different stakeholders. The security of the information may also be ensured through the use of cryptography [XXXI].

Presently companies involved in food supply chain are facing many challenges such as delay and defaults in the distribution of goods, Food origin tracing and high workforce to meet the desired demand of all stores. To address these issues, companies have digitalized their procedures to facilitate stakeholders and expand their business in the supply chain, but with digitization may also increase the risk of attacks on their databases and hackers can to modify, steal or delete data [XXVI]. Especially in agribusiness attack of hackers on data may cause serious issue whereas as Blockchain platform can provide a secure solution to these problems with decentralized, automatic and trusted data and transportation management as shown in figure 5 [XXX].

Figure 5: Blockchain and IoT based Smart agriculture ecosystem

I.iv.a. Control with IoT

Checking the quality of crops, plants, and animals is also a very significant process for all farmers and the IoT can extend support and make its contribution here. Quality of soil, Irrigation activities pest and diseases and many other farm-related activities can be monitored and control through appropriate IoT software installed in smartphones, computers or tablets [XXVI].

Therefore IoT combination with the blockchain will make the agricultural food supply chain more reliable and fruitful by monitoring the whole process [VII].
I.iv.b. Companies decentralization

In the world agriculture market has occupied by the large companies and they are imposing their terms, set prices and making an agreement with farmers what actually, farmers will grow in the upcoming season. Despite of unprofitability farmers are bounded to implement their conditions because they are mostly depending on large corporations. Blockchain has the ability to change it once and for all [II].

I.iv.c. Prevention of raw-material

Farmers also not sure that either they are buying good quality grain, seeds and compound feedstuff to breed healthy animals, produce a high-quality crop, juicy fruits, and vegetables. The genuineness of all raw materials is not confirmed. If farmers produce and sell meat and crops of low quality, then there will be a trust deficit between farmers and customers. Blockchain can play a tremendous role here, farmer will able to see what type of raw material they are going to purchase [XII].

I.iv.d. Food origin tracking

When you purchase fruit, or mutton in a superstore, can you confidently say that you bought a safe food? Although the store representatives will show you all relevant documents and certifications, you are not known how the food was stored earlier and whether it contains any harmful bacteria or not. Blockchain can provide access to customers to find out everything about each product [III].

I.iv.e. Permanent record keeping

Blockchain has the ability to keep a record on a permanent basis for future correspondence [XXIV]. Researchers designed an AgriBlockIoT a decentralized, Blockchain-based traceability solution for agricultural food supply chain management that is capable to flawlessly assimilate IoT devices producing and consuming digital data along the chain. They well-defined a classical use-case within the given vertical domain, named farm-to-fork, and designed and installed such use-case, achieving traceability using two different Blockchain implementations, namely Ethereum and Hyperledger Sawtooth. Lastly, they assessed and matched the performance of both the deployments, in terms of latency, CPU, and network usage, by highlighting their main pros and cons [XXI].

II. Motivation

The related literature indicates that a lot of food tracking mechanisms are available for the food supply chain, however merely in few downstream stages vertically integrated. The information regarding product is also stored in databases which make it more challenging to make an end-to-end traceability. Only limited research work is available on the use of blockchain and IoT in food supply chain. Yet, an evaluation among current data systems and an innovative blockchain and
IoT model is lacking which motivated us to propose an optimized model based on blockchain and IoT to overcome these challenges and to provide a fair and smooth communication channel to all stakeholders. Hence, we have presented a scheme which will be a novel model in this domain for the transformation of traditional agriculture field to smart farming, taking into consideration both blockchain and IoT characteristics.

III. Proposed IoT with Block-Chain Smart Farming Model

It has proved from above research work that the IoT combination with blockchain technology can play a tremendous role in smart agriculture and food supply chain and all stakeholders can get many advantages without getting help from trusted third party. In this paper, we propose a smart model based on IoT and blockchain architecture to perform smart farming activities through innovative ways as shown in Figure 6.

![Figure 6: Block diagram of IoT with Block-Chain Smart Farming Model](image)

Our smart model has three parts IoT, blockchain and retail market. IoT part is related to data generated through the use of sensors arranged on the farm. data will be generated through IoT devices and will be recorded in the system, for instance, production information will be recorded during the production stage including...
essential information and production log information such as product name, origin, etc, and later product growing information will also be recorded at multiple times and all stakeholders will have access to see this information. The second part is related to the data storage, consensus, encryption, decryption, and verification function which will be performed by blockchain. It will run smart contracts to execute the corresponding logic at specific points in time which will increase scalability, simplify the process and reduce cost. The third part is related to the retail market; after completion of the production process goods will be delivered to successful bidders (distributors, retailers).

Figure 7: Smart Model proposed shape

III.i. Step wise description of smart model.

III.i.a. IoT function

IoT will perform following functions.

**Step 1:** IoT devices will monitor crop health and generate information to provide support to farmers for making a timely decision related to crop growth and collected information will be saved on the blockchain.

**Step 2:** To get more insight information machine learning is used it will provide more depth information like crop yield prediction, crop growth factor, demand forecasting and recommendation to improve crop quality. Farmers will also get help from machine learning algorithms to make improvement in the irrigation system. The data collected through machine learning will be saved on the blockchain to empower stakeholders like farmers, investors, innovators, and retailers to get access fairly.
Step 3: The high valued data collected by applying machine learning will be stored by IPFS (Interplanetary File System) on the blockchain in decentralized server to avoid single authority control and to reduce the risk of data hacking whereas the available systems are storing information in the centralized server which can be hacked or failed, after those smart contracts will be generated by blockchain to define rules.

The function of Smart contracts is to facilitate specific stakeholders to exchange data stored on the blockchain and at the same time information will be shown to each agriculture market member this will provide a unified platform to improve efficiency.

III.i.b. Food supply chain process

Step 1: In Smart model IoT devices are used to provide important information related to the crop. Then taken data will be kept in the by blockchain by IPFS.

Step 2: When the crops will full-grown, companies dealing with food processing will get access to the bidding platform to start bidding. After completion of bidding process crops will be delivered to the plants through vehicles enabled by IoT to keep maintain the desired temperature. It will be necessary to validate the bid through smart contracts, and then the crops will be put into process and companies will store all information on the blockchain that were recorded at each step during the whole process and this information will be accessible to all stakeholders to confirm that food which has supplied from plants have good or low quality. Blockchain will make sure that the desired criteria have met at each step.

Step 3: After processing of food items wholesalers and retailers will access bidding platform to offer a bid for the product they want, after completion of the bidding process the food products will be dispersed to successful bidders through vehicles enabled by IoT to keep maintain the desired temperature again. Blockchain will track the whole process throughout the supply chain, which will help food businessmen to conduct food recollections or inquiries rapidly.

Step 4: Blockchain will keep maintained all data, from initial stage to distribution stage for current or future check of all related information like consignment numbers, food handling, date of expiration temperature at which food was kept and other relevant information.

III.i.c. Controlling Weather Crisis

While growing different types of crops farmers often face unpredictable weather conditions. Therefore, for the survival of crop predicting and monitoring of weather conditions are important.
Step 1: Agricultural weather stations will be placed within the farms which will provide important information such as the temperature of the soil, air temperature, rain prediction, breeze speed, etc. This information will be kept in the blockchain to help farmers to make timely decisions.

Step 2: In case of crop damage during a weather disaster, Farmers will rapidly place a request to get the crop insurance claim through the blockchain and after the approval of claim request farmers will automatically get the requested amount.

III.i.d. Managing Agricultural Finance

In managing agricultural finance farmers often faces problems like lack of transparency, previous credit record and implementation of the contract, these are challenging issues between formal financial authorities and farmers. Limited access to financial services may impact the performance of agricultural value chains and farmers cannot improve the yields, as well as buyers, may also be impacted. Blockchain will provide help to farmers will bring transparency in procedures of agricultural finance through mutual control access.

Step 1: Every transaction will be recorded in the blockchain and access will be provided to all parties to bring transparency in the system.

Step 2: Blockchain has the ability to record information on a permanent basis where it can be a good source for verification of transactions and audit can be conducted easily through blockchain ledgers without getting information from relevant parties. Automation in the process of conducting audit will bring more transparency and the cost will also be reduced.

IV. Advantages of Smart Model

![Figure 7: Advantages of Smart model](image)

IV.i. Support to farmers and ensure food safety

Crop failure is a common problem faced by the farmers around the world, it always occurs because of critical climatic circumstances, such unpredicted rainfall and unreliable weather condition secondly farmers also need to monitor factors like
soil quality, pesticides, crop diseases, water requirements which can impact their crops. To solve these problems we have connected IoT devices with the smart model which will help farmers to monitor all these factors to initiate timely action. Another problem that needs much attention is safety of food. Safety of food denotes to supervision of all food production process to ensure the delivery of quality food and reduce the risk of individuals becoming sick from foodborne illnesses. Our proposed model will monitor the whole food production process start from farmer to consumer.

Iv.ii. **Improve food traceability**

No one on the world can surely say that he has bought a good food to eat; here our smart model with blockchain infrastructure can solve the problem of consumers by providing them access to know where and how their food initially originated and how it reached to them. Traceability is another fabulous feature of our smart model which will allow farmers to record the status of their crops and track the whole the process, planting, harvesting, storage, and delivery. In this way, food frauds will be reduced and farmers will be paid fairly secondly through tracking system other stakeholders in the supply chain will also able track the whole process and trust will be developed among all parties.

Iv.iii. **Improved farmers productivity**

Presently, the majority of the farmers depends on different agriculture-related software to record their data and they have no common platform due to which they need a lot of efforts and bear cost. Our smart model will permit farmers to record all information on a single platform and everyone can easily access according to his need.

Iv.iv. **Fair mode of payment**

Numbers of problems currently exist that make it hard for the farmers to acquire payment for their crops like payment through wire transfer which often takes a substantial amount to transfer money due to which farmers profitability may decrease.

In our proposed smart model smart contracts based on blockchain will ensure payment to farmers through a fast and automatic way without being charged. Farmers will able to get paid for their produce immediately after delivery. Another feature of this model is smart contracts through which the role of middlemen has been eliminated; farmers often face issue to sell their good in the market at fair worth and they often need helps from middlemen for which they have to pay extra amount or they can be cheated by mediators. Through smart contracts, farmers will interact straight away with retailers and they will be able to get a fair price for their products.
V. Validation of Proposed Scheme

Proposed Scheme is shown in Figures 10(a) and 10(b). As we do not find such a scheme in literature, hence we have validated our scheme with our own scheme as presented with the blue plot in both figures. The blue plot indicates throughput in regard to implementation of IoT in agriculture sector with deployment of various nodes in the field under monitoring. The results themselves proved to be quite promising. The red plots indicate an improvement of our initial scheme with the utility of blockchain along with IoT. The results show a tremendous raise from the single IoT based scheme which validates the performance of our scheme in contrast to the various nodes deployed and tested in the agriculture field.

Figure 10(a): Throughput versus node deployed
VI. Simulation results and discussion

For the purpose of simulation, we study our proposed smart model with 120 IoT nodes and 20 block producers scattering over a 2km x 2km area. The DNN involved in the proposed model was applied using PyTorch, a flexible and is speedy deep learning system. We used PyTorch 0.4.0 with Python 3.6 for software arrangement in Window 10 system. For various simulation situations, we accomplished this system with different preliminary parameters. The settings of parameters used in the simulations are shown in Table 1. Four baseline schemes are measured in the simulation for comparison purpose and proposed scheme without consensus.

Table 1: Simulation parameters and Value

| Simulation Parameters                  | Values     |
|----------------------------------------|------------|
| Coverage area of node                  | 2km x 2km  |
| Total numbers of nodes N               | 120        |
| Total numbers of block producers K     | 20         |
| Transaction size (average ) X          | 200B       |
| Stake of node Zn, Tn                   | 1-50 Token |
| Computing source of node Zn, Cn        | 10-30 GHz  |
| Transmission rate of node Zn, Rn       | 10-100 Mbps |
| Limit of block size S                  | 8MB        |
| Block interval (Maximum) T             | 10s        |
| Threshold value of decentralization ns, nl | 0.2, 0.3  |
| Number of intervals that new block should be validated, w | 6          |
| signature verification verifying MACs, a, b | 2MHz | 1MHz |
| The size of batch, M                   | 3          |
VII. Performance of Convergence

The convergence performance of our proposed scheme is shown in Figure 11, from this figure we can examine that at the start of learning process transactional throughput is very low. But with increase of events throughput also increase and after 4000 events it reach to stable position which verify the convergence performance of our proposed scheme. Apart from that it can also be verified that proposed scheme can receive the higher throughput than other three based lines which show the rewards of proposed Scheme.

![Figure 11: Convergence performance of different schemes](image)

VIII. Conclusion and future work

Nowadays food supply chain companies are concentrating to find the actual food source and track the whole process of food production from food origin to end consumer which is one of the most challenging tasks for them. In this research work, we made an attempt to address this issue by providing a solution to this problem by creating a smart model based on blockchain and IoT technologies with our own understanding grounded on background literature. We have proved in our research work that blockchain in combination with the IoT can be more beneficial to track the whole process of food lifespan, avoiding a large amount of food wastage, detect and eliminate the cause of foodborne disease within moments whereas the current systems are taking weeks. In addition to that proposed system will offer better consumer self-assurance which will reveal in sales and customer pleasure. In our future work we will develop software for a proposed model for practical implementation.
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