Role of Blockchain for Enhancing Food Supply Chain Management

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ABSTRACT

Major component of food production is food traceability. There is accessibility of different systems for food traceability through producers can ensure quality and safety of their goods. Immutable ledger i.e., Blockchain is the revolutionary technology that was in beginning concerned for Bitcoin cryptocurrency. Now its application in other fields include food traceability in supply chain management is being explored. Blockchain allows individual and companies to engage in business without a need of trusted authority. There are various shortcomings with existing system available in market for food traceability such as lots of documentation is required for business. It requires around signatures of 30 entities when product is shipped from one country to another which leverages high cost. Existing system are centralized, outdated, lacks data sharing and interoperability. Blockchain based traceability system will digitalize the work hence reducing the shipping cost. Blockchain can entirely change the movement of products from farmer to retailer owing to its security, transparency and distributed nature. Blockchain have some unique characteristics such as immutable, smart contract, decentralized, timestamp which will boost the productivity of existing food supply chain management. In this paper we have discussed about role of blockchain in food supply chain management, brief introduction to blockchain, literature review by other researchers, comparative analysis of the background study undertaken, drawbacks of existing system, enabling Blockchain with IoT, potential advantages and shortcomings of blockchain implementation in food supply chain.

1. INTRODUCTION

Food traceability consist of various stages: tracing food from different stages of production, processing, distribution, transportation and retailing [1]. Traceability involves product movement can be traced from anywhere at any point of time [2]. Data is stored on block of chains. Data gathering is done during supply chain so that customers have knowledge about the origin of product, expiry date. Customer can take appropriate decision based on accurate information regarding product origin and environmental aspect. Developed systems lacks trust and transparency of user [2]. Blockchain was first coined by Satoshi Nakamoto in year 2008 for doing financial transaction using cryptocurrencies. From that time cryptocurrencies such as Bitcoin, Ethereum has earned lots of public attention for performing digital transactions. Due to advent in Blockchain technology, it is expected to fulfill the demand for productive and sustainable food supply.

There would be immutable contract among various stakeholder that will increase transparency in supply chain. Blockchain eliminates the involvement of middleman which directly changes the way trust is granted in agriculture sector [9]. Product status can be recorded at every stage from source to destination. Even companies can see the demand of product and which group of people are buying them. Real time reporting of problem such as fraud activities or black marketing can be addressed through smart contract. Smart contract validates the transactions and user gets rewarded in form of tokens. Blockchain in food traceability can increase the trust between producer and consumer. Producer can update the information on Blockchain about the product such as origin, quality, ingredients, availability thus increasing transparency of data [3]. End customer concerns about how food is produced, safety and availability of product is also addressed as they are getting reliable information [8]. Figure 1 represents different stages of food production. There is huge auditing when product is moved from farm to customer which includes human error like deletion, replaced or lost. Blockchain provides better traceability and security as it relies on smart contract which removes manual documentation. Blockchain is distributed thus every stakeholder have access to same information,

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lowering down errors due to communication gap [4]. Data validation is done quickly which is improving the quality and cost reduction at the same time.

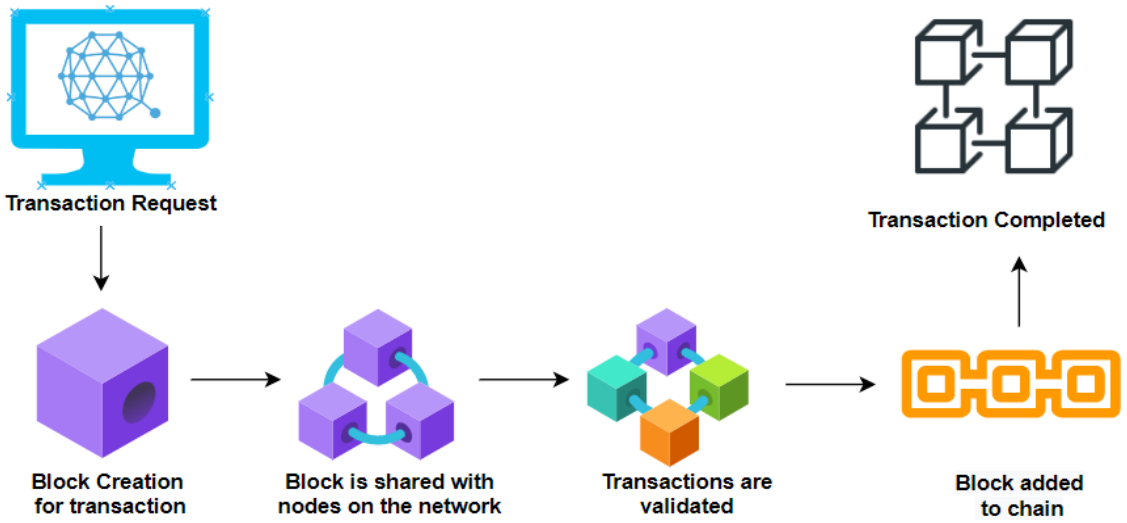

Fig. 1. Blockchain Workflow.

1.1. Overview of Blockchain

Blockchain is an online global database that anyone can use it. Traditional database is owned by banks and government. Blockchain is a decentralized system where decision making is on the hands of the nodes on the network instead of central server. Blockchain contains series of block connected in chronological order [5]. The first block is known as genesis block which has hash value 0. The subsequent block contains hash of previous block. Blockchain consist of index, timestamp, hash, hash of previous block. Index starts from zero and identifies the order of block. Timestamp states the duration of creating block. Valid block has three zeroes in beginning. Data manipulation will change the hash of previous blocks in addition to current block. Faking documents, transactions and other information is quite impossible [12]. Blockchain stores the information on the computer network permanently. Millions of users on the system make it hack-proof. Blocks have timestamp and contains link to previous block [6].

Changes cannot be made once a block is created making it immutable. For altering with the data, user need to do alteration with the preceding blocks and 51% of users should agree with it. Cryptographic algorithms ensures that data is processed by authorized users. Blockchain most famous application is Bitcoin. It is a digital currency which don't involve any third party for source of trust. Blockchain verifies the ownership of the user for transaction [7], [36]. Based on peer-to-peer network where every computer contains a complete copy of the record and compared it to other systems to confirm the accuracy of data.

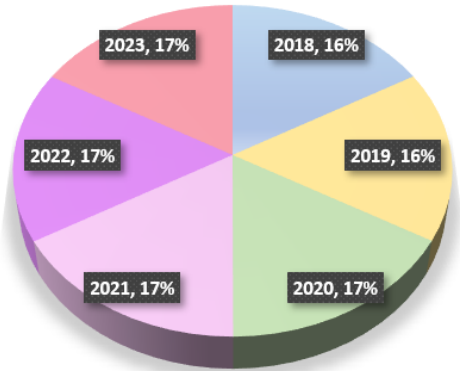

Fig. 2. Rise of Blockchain in recent years.

Smart contract are small computer programs just like the notary in the real world. Unlike in traditional system legal contract demand high charges and third party for trust, Smart contract just like a digital agreement that has pre-defined rules set between different nodes on the system without involving intermediaries [8]. It only works when predefined conditions are satisfied else it will reject the request. Blockchain is an append only distributed ledger where deletion or tempering with blocks requires consensus of all the nodes on network making it transparent. As traditional system involves third party, so security is compromised.

Blockchain uses cryptographic private and public keys to maintain security in smart contract. Smart contract has digital signature using private keys and have public keys which is distributed among different entities. Smart contract is available 24*7 with full transparency. Blockchain

supports Proof of Work (PoW) which refers to a consensus algorithm [9]. Miners refers to group of individual who compete with others to record transaction on blockchain Miners solve a mathematical puzzle such as integer factorization, hash function or creating valid block and after successful creation of block they are rewarded with tokens [10].

1.2. Motivation

Covid-19 has reduced the production of goods and services. It has greatly impacted global production. Food traceability system for tracking the outbreak of disease and pollutant is given keen importance during pandemic [10]. How to know that the fruits you buy are fair trade? How to know which products are real? We simply don't know. We need to have record of stages of product development. Consumer are concerned about the food quality and security thus raising demand for reliable, secured, and efficient food traceability system [11]. Around millions of patients have reported cases of foodborne diseases and lakhs of deaths are reported worldwide every year. Some food system hardly provides accountability, transparency, traceability and they are centralized which make them more prone to security threats [11]. Blockchain is a distributed network where data for the food supply can be transparent and immutable from farmer to consumer. Illegal activities could also be prevented by proper implementation. As Blockchain is decentralized which increases the privacy and security of transaction. With Blockchain we can track previous stages of the product you purchased. Every node on the network is accessing the same details so tempering with data is not possible [12].

1.3. Research Questions

RQ1. What is the existing solution in the market for food supply chain management? Are those solutions best alternative for Blockchain solution?

RQ2. What would be the potential advantages by adopting Blockchain in food traceability?

RQ3. Is there any issue with successful implementation of Blockchain?

RQ4. How will food supply chain system get affected by Blockchain post pandemic?

2. LITERATURE REVIEW

There is lots of background work undertaken by multiple researchers who have proposed blockchain solution in supply chain management. Pertaining to its immense capabilities and practicable importance, research is still going on. Food traceability is the vital parameter in food industry [12]. Previously there were various papers published in this field but few of them entirely focused on a particular field such as agricultural or dairy products [13]. We have discussed about some of the searchers in this area below.

Yu Gong et al. [1] in their review paper have discussed about few propositions and challenges of food supply chain. Trust and traceability issues can be addressed by granting access to authorized users without intervention of central system. Digital records save human power and eliminates data fra ud. Combination of IoT and Blockchain provide intelligent and genuine data exchange. IoT sensors such as humidity and temperature can measure the information in real time to maintain the quality of food products. Once the appropriate values vary from its range then smart contract will be executed automatically and users will get warning about degraded quality of product. Their study revealed that companies implementing the blockchain solution lacks proper understanding about the technology. Scalability issue when transactions take place in large scale. Blockchain is still in immature stage so inviting all the stakeholders on the board is a challenging task (2019).

Thomas K. Dasaklis et al. [2] proposed a secure and tested architecture on dairy products food traceability. Three smart contracts are presented through Ethereum based private blockchain to show performance of the architecture. First smart contract deals with interaction between stakeholders internally with respect to raw material, temperature and location. The interaction among product and stakeholder is mentioned in second smart contract. The last smart contract deals with process management. Every time when smart contract gets refreshed on fulfilment of some condition, an alarming notification is received by stakeholders who can verify the content of the product simultaneously. Access control is set so that authentic account can only modify the information thus guarantees privacy. Authors concluded it by stating the efficiency of their product quality with respect to trust, auditability and resilience (2020).

Julia Lange et al. [3] proposed a two-level architecture using public permissioned blockchain for food traceability. Checksums and information related to traceability is stored on public domain and sensitive data is managed by internal entities. Permissioned Blockchain have features of both public and private Blockchain which defines particular permissions to a group of users which makes it highly secure. Blockchain provide solution for inaccurate, unavailability and leakage of data. Promising output with fault tolerant algorithms is an added advantage of the system (2021).

Muhammad Salek Ali et al. [4] proposed AgriBlockIoT, Blockchain and IoT integrated solution for agriculture food supply. IoT smart devices depend on centralized system which result in security attacks and lacks transparency. Using a shared ledger that relies on consensus algorithm for verification would be a solution. Stakeholders include provider, producer, processor, retailer, distributor, and consumer. Performance key terms such as network usage, latency and CPU load is measured in Ethereum platform and Hyperledger Sawtooth. Smart contract runs when a

condition is fulfilled Hyperledger Sawtooth have more bright result as compared to its counterpart. Both the Blockchain implementation have their specific roles. Ethereum has better consistency where Hyperledger Sawtooth has faster response (2018).

Nikolaos Peppes et al. [5] have discussed about the functionality of blockchain food traceability spplication and existing system available in the market. Available solutions lack trust, interoperability, security, low energy consumption, data sharing even with rapid technological development. Research studies on Blockchain have started just few years ago and its results are promising through irreversible data storage. Maintaining regulations, scalability, stakeholder participation, ownerships possess some challenges of Blockchain. The proposed system requires some more implementation such as reduce cost, risk and time, increased transparency and truthfulness (2020).

Francesc X. Prenafeta-Boldύ et al. [6] have demonstrate the blockchain implementation in food production. In 2018, World Wildlife Foundation opted for Blockchain food traceability solution to control illegitimate tuna fishing. Intel in 2017, implemented the technology for sea food traceability. Ireland Craft Beers was the first corporation to use Blockchain in beer sector. Start-ups such as Bext360 are providing economical help to farmers by providing tools. Blockchain along with some more technologies such as RFID, NFC, ICT, IoT are proposed for efficient food traceability (2019).

Hang Xiong et al. [7] discussed about the Blockchain application for tracing fraud, real time updating, transparency, reliable data which makes farmers less vulnerable. Climate change effect both crop and livestock. Through smart contract payment are done automatically and on time when farmers face loss under agriculture insurance scheme. Smart farming system by IoT and Blockchain where blockchain data can be accessed on users smart phones. Reduction in transaction cost will increase the revenue for farmers. Small and big farmers will be benefited from blockchain implementation as small farmers will easily participate in insurance scheme. Big farmers can easily integrate all the farming data at one place (2020).

Fran Casino et al. [8] have introduced an effective Blockchain solution to overcome the barriers of traditional food supply chain like integration, security and sharing records. Smart contract based on private blockchain is designed to enable different function of system. Manufacturers, retailers, and distributer provides the details on smart contract which was taken in account for authenticity. Blockchain challenges regarding storing large data and scalability should be taken into consideration to make a system more feasible and trustworthy. Multi-tier system would increase the scalability issue by consuming more time for verification of transactions. Only limited number of stakeholders are involved instead of disparate members for more successful exploration (2019).

Aleksandar Erceg et al. [24] have analyzed the implementation of blockchain for local supply chains. Proposed a multi-layer blockchain architecture. The business model layer comprises of products, participants, end users, time of ordering the product, and handling inventory. The technical part resides in the platform layer. Transaction forms a block as soon as it takes place. Information about date, source, and time is stored inside the block. Blockchain's distributed nature verifies the block. The application layer involves smart contract and IoT devices. A smart contract allows the automatic execution of transactions without allowing third parties. Through IoT, sensors are embedded with physical devices for continuous monitoring (2022).

Shashank Kumar et al. [25] discussed about integrating IoT and Blockchain for the supply chain. Blockchain provides high reliability and security whereas IoT enables real-time management and transfer of data quickly. Industry 4.o has impacted supply chain development in a very transforming way. Fewer nodes in the blockchain, storage issue, and transferring large volume of data is a few barriers identified (2022).

Marcus Foth et al. [26] mentioned about the adoption of Blockchain and IoT for enhancing data integrity. Undertaken a project on Australian beef for its protection and verification. Developed a framework with IoT and decentralized blockchain for pampering the need for a reliable food management. Introduced 'common knowledge' for the beef supply chain. Reviewed prior papers that were addressing supply chain issues with these technologies (2022).

Vasileios Tsoukas et al. [27] in their review paper talked about boosting up food supply chain sector by making use of blockchain's traceability and distributed features. Trust of end user can be maintained by building a reliable and sustainable food traceability solution. The authenticity of the order can be ensured by tracking the place of origin, making records of each transaction, real time and secure digital payments can be achieved. Goods can be traced with suppl chain by using unique IDs. Prior information about date of expiration can also prevent food wastage (2022).

3. COMPARATIVE ANALYSIS OF WORK DONE BY PREVIOUS RESEARCHERS

Various authors have provided Blockchain solution for enhanced food supply chain management. Most of the authors have done it for agricultural products [13-14]. Other authors have carried their study on Blockchain and IoT solution. For instance, Muhammad Salek Ali et al. [4] proposed AgriBlockIoT, food traceability system with Blockchain and IoT. Reliable timestamped Blockchain and IoT based green farms framework was designed for general use. It was compared with single authority or centralized system in food supply [14]. Table 1 presented the solution for food supply chain based on blockchain.

Table 1. Solution for food supply chain based on blockchain

Authors	Technology	Main Stream	Advantages	Challenges	Performance Parameters
Yu Gong et al. [1]	Blockchain	Food Traceability	Transparency Authenticity Efficiency	Lacks deep understanding Initial stage Less stakeholder participation	Transactions throughput
Thomas K. Dasaklis et al. [2]	Private Blockchain	Dairy products food traceability	Distributed Secured Resilient Auditable	Lacks trust Scalability issue to authenticate records Interoperability	Scalability of number of participants
Julia Lange et al. [3]	Public permissioned blockchain	Digital traceability system	Consensus algorithm Interoperability	Requires system validation	Full node or Partial node ratio
Muhammad Salek Ali et al. [4]	Blockchain (Ethereum and Hyperledger Sawtooth) Internet of Things	Agriculture food supply	Transparent Auditable Decentralized Integrated with other software	High cost of deployment	Latency Network usage CPU load
Fran Casino et al. [8]	Local private Blockchain	Traceability of food	Security Accountability Medium user complaints Medium response time	High cost Simple FSC network Scalability	Response time Food quality Consensus mechanism

4. DRAWBACKS OF EXISTING SUPPLY CHAIN SYSTEM

In global marketplace establishing a resilient supply chain management for food traceability is becoming more competitive to balance profitability and market share 15]. Today's supply chain demand is more challenging due to outdated and fragmented distribution. Supply chain ensures customer about the product availability, what customer wants and where they want, quantity of product [16]. Supplier has to meet the demands of the consumer which are uncertain.

C. Cheng et al. [32] in 2018 proposed a solution based on central authority system. Extensible markup language (XML) stores the information regarding product through printed tags along with traceability codes and stakeholders can access the information by a central database. The framework is efficient and precise with limited volume of data [20]. The limitation was the system inability to manage huge volume of data which consumes more computational power. Customer want to know about from where the product is coming, what all are the ingredients added thus makes it more crucial for accurate data about the product traceability. Lack of transparency will expose the business with unnecessary risk and customers will lose trust which will lower down the profit and sales [17]. Traditional manual paper work and using outdated system cause delays and errors in data exchange. Blockchain is a distributed ledger where users are allowed to perform transaction in real time. Once a record is added then it's become permanent so cannot be hacked. Stakeholders can access to trustworthy data regarding product quality [18].

Supply chain is fragmented that prevents the efficient food traceability. In a universal supply chain, many entities are involved that are not aware of each other's action. Stakeholders should communicate with each other for better results while maintain the business reputation. Food fraud is a rising challenge that is being encountered frequently nowadays in central food supply monitoring. Blockchain is a decentralized system which enables forgery proof and transparent transaction [19]. Unaltered transactions provide trusted environment in the existing situation of pandemic.

Business has a pressure on product availability as customer expectations changes frequently. They have to make the product immediately available on online but also in offline stores. Involvement of third party where products are available at brand website as well as through retailers. Efficient warehouse contributes for overall business development for accurate decision making based on distribution and demand [20]. As we are moving towards more technological advancement cybercrime will also rise. For business data is very important, data theft will be more common. Technology not only replace man power in future but require humans to have more advanced skills [21].

5. ENABLING BLOCKCHAIN WITH IOT FOR FOOD SUPPLY

Blockchain allows to store data globally on many servers where everyone's record in real time being visible to all users. Internet of Things deals with the mechanism in which objects are interconnected to each other for transmitting data on the network platform through sensors, software by eliminating human intervention. By integrating both these technologies enables us to develop a secure, authentic and everlasting solution of processing records through smart devices [22]. Blockchain strengthens IoT by ensuring privacy and efficiency of IoT devices [23]. IoT enables smart devices to transfer records to blockchain ledgers to be used in distributed transactions among other temper-resistant data.

There are numerous smart devices and are still increasing day by day. The greatest challenge with the pharmaceutical industry is about rising prevalence of forged drugs. Blockchain IoT enables the participants involved in drug production to be accountable and upgrade the blockchain with required details [23]. Because of transparent nature of blockchain, participants can view and track developing, distributing and shipment of drugs from their smart devices. Data obtained through this will increase every minute. Home security system in real time can be monitored remotely through Blockchain IoT.

The conventional centralized method for obtaining data by smart sensors have security and privacy issues. Blockchain can overcome these problems by eliminating centralized systems and resolving security concerns. Inevitably managing high amount of data also increases cybercrime. The current techniques are efficient but will not support for longer period. Due to high installation and operational charges of cloud services, IoT solutions are very costly. With decentralized blockchain, these issues can be addressed efficiently. Water leakage is the major problem which causes huge loss of water. Collaboration of these technologies will give advance solution for safe and more efficient water monitoring system in the cities [24]. Blockchain IoT can determine the water usage and automated water shutdown if leakage is detected. By reducing ecological footprints and transparent network over the supply chain, food industry can be reformed through Blockchain IoT. It can boost the agricultural department to a larger extend by deploying IoT sensors in the farms and transmitting that information directly to blockchain. Implementing peer to peer network to handle vast amount of data across wireless devices will lower down installation and operational cost [28].

IoT is a novel technology that provide real time monitoring of products and its contamination [25]. IoT applications optimize food supply by addressing the momentary problems in real time. It also addressed problems such as lack of communication, visibility and transparency. Feng Tian [26] in year 2016 in their study revealed about some insight of applying Radio Frequency Identification as well as Near Field Communication for supply chain management. Various Research and Development communities are also adapting Wireless Sensor Network (WSN) and RFID for inexpensive connected devices for remote monitoring of food quality and transportation [27].

Muhammad Salek Ali et al. [4] have worked on case study "from-farm-to-fork" for their proposed a framework "AgriBlockIoT" on Blockchain coupled with IoT. IoT sensors are benefited from trusted and decentralized system using cryptographic algorithms. Organic product certification and alert during any anomaly through smart contract. Consumer make use of immutable, distributed system which was implemented on Ethereum and Hyperledger Sawtooth for better analysis [28]. Food quality also depends on external factors such as temperature, humidity, location which can be easily traced simultaneously with IoT smart sensors [29]. Ethereum have better trial result when it was compared with Hyperledger Sawtooth with regard to network usage, load of CPU and latency [5]. IoT can reduce the human labor and errors which will increase system efficiency. Smart contract will automatically execute when anything goes out of range for IoT sensors which will maintain the food quality (Tian, 2017).

IoT with Blockchain will provide improved communication, data analytics and data management in logistics sector. There are security concerns related to IoT sensors. Blockchain can keep the records of transaction but tempering with IoT sensors can damage the products without getting any alert from Blockchain users. In spite of adopting IoT application, complex food supply chain system is making traceability more difficult. Incomplete information can lead to food insecurity and poor consumer health [30]. Tian (2018) developed a IoT and Blockchain solution to make sure that data entered in the traceability system is authentic and transparent. Dasaklis et al. [2] in 2020 in their framework have used three smart contracts on Ethereum based private Blockchain where modification can be done by specific nodes depending on their responsibility. Temperature is directly accessed by IoT devices connected to Blockchain. Immutable, auditable, transparent, aerotolerant system can be created with Blockchain and IoT for agriculture supply chain [5]. Another system on agriculture food supply was proposed using Blockchain and IoT combined with Enterprise Resource Planning and low-power wide-area network.

6. BLOCKCHAIN IN FOOD TRACEABILITY

Blockchain have promising opportunities to increase productivity, transparency and reducing cost in regulating supply chain [31]. Deploying blockchain in food supply administration can help the users to look into quality, location, date, price and other certifications required for

more efficient functioning. Food industry have to prioritize on production, processing, post harvesting, transportation and retailing and special focus when dealing with seasonal products. Delay in shipment and temperature variation can directly affect food quality. Smart contract builds a trusted atmosphere on ownership and validity of product certification. Thus, Blockchain removes the entry of fraudulent food.

All the partners have shared information in supply chain. Quality, location, raw material, status of product can be traced at any point of time through remote monitoring. Transactions are stored securely so risk related to data hacking and stealing can be brought down. Stakeholders maintains the record stored on the network that are permanent. Stakeholders can save the copies of record, have direct access and can retrieve it on demand anytime. Manufacturer can track the quality of raw material and on the other hand customers can rack the origin of the product. Transparent data helps brand owners to quickly identify the source of contamination. Without disrupting the whole supply chain only food fraud can be managed potentially.

Information that is accessible on network is error free and at the same time visible to all available nodes hence maintain trust between the stakeholders about product manufacturing, processing and distribution. It enhances customer decision making power as it provides sustainable food practices by digitalizing and global sharing of records [32]. It also reduces food borne diseases as counterfeit products are reported about foodborne outbreak. Number of victims of the outbreak will be reduced because all the records are saved on the system. None of the stakeholders can erase the history and escape from the responsibility.

Blockchain removes the intermediaries thus reducing transaction fees. Simultaneously intermediaries will not be paid by farmers and manufacturers. Costumer will get high quality of products or goods from reputed brands at reasonable price [33]. Food traceability framework based on Blockchain can keep live track the quantity of goods wastage and food items can be rescued in entire process, thus increasing the production and reducing loss of product. Food recall issue can be addressed by retrieving the data and separating the products from suppliers. Smart contract can minimize the human labor, save unnecessary money spent on manual work. Automatic payment is done to producer when product reaches the warehouse.

Case Study on Walmart

Walmart and IBM combinedly designed a solution based on Hyperledger Fabric for addressing shortcomings of food supply administration. Two projects of Proof of Concept (PoC) was expected to check the validity of the system. Tracking of pork sold in Walmart's China stores and other project on traceability of mangoes sold in US stores. Food tracking system based on Blockchain was tested successfully. Authenticity of certificates was a major issue for pork in China. Hyperledger fabric allowed more trust regarding uploading of certificates. For mangoes in US, time of origin was reduced from 7 days to a few seconds only. Walmart went through different blockchains such as Burrow, Ethereum etc. At last they finalized Hyperledger Fabric as it is a permissioned blockchain and the best one for fulfilling the requirement of an enterprise. Chaincode is a smart contract for Hyperledger Fabric that contains the main logic of the food system. Walmart keep track of 25 products from 5 various suppliers using the blockchain. Few products such as leafy green vegetables, strawberries, mangoes, poultry and meat. Any product's place of origin can be figured out. Items can be tracked from Walmart to its original location in a matter of seconds.

7. CHALLENGES OF BLOCKCHAIN

Blockchain provide food safety by enabling information traceability about the product from its creation till end in food supply chain [34]. Many stakeholders have less knowledge about the technical aspect of the system [5]. Solution will be more effective when Blockchain is fully integrated. Combining different other components with Blockchain makes the solution more complicated. Below we have talked about the persistent challenges of blockchain that is acting as a bridge for its worldwide acceptance.

7.1 High Resource Consumption

Lots of resources are needed to move an entire supply chain system on a Blockchain platform. Immutable data is the prime factor that differentiate it from other technologies. Humans have tendency to make errors so entering incorrect data will be more challenging as compared to other technological application [35]. As the number of transactions will increase, more resources are required for further processing.

7.2 Data Protection

Sharing the sensitive information with appropriate users by granting access control to authorized users. Set access roles to those who are involved with you in food supply chain. Public Blockchain solution are easy to develop using smart contract but the cost can be too high or have slow functioning.

7.3 Low Scalability

There are various entities involved in supply chain that depend on different tools. Merging all the tools with Blockchain is a difficult task. Not all the stakeholder wants to join the supply chain which incorporates Blockchain due to system overload and security concerns. Blockchain can save records securely but as the number of records increases, power consumption also increases. It is still facing scalability issue [35].

Fig. 3. Blockchain in Food Supply Chain.

8. CONCLUSION AND FUTURE SCOPE

Blockchain is an emerging technology which as potential to create a huge business value in real world. Blockchain supports interoperability which allows all the vendors from the supply chain can communicate as well as transmit the data at remote locations. Smart contracts are small computerized programs that resides within the blockchain. These smart contracts are executed only when predefined terms and conditions got satisfied. Its technical functionalities are not evaluated completely. There are various food supply chain research papers but many of them have theoretical implementation. Authors have provided Blockchain solution with IoT that increases the security of IoT sensors on a decentralized network. Several problems in food supply chain such as auditability, interoperability, authentication, integrity, security and high cost can be addressed as Blockchain comes up with a decentralized and trustworthy environment.

Validation speed of Blockchain system comes down when huge transactions are done. We have discussed lots of advantages of Blockchain based supply chain. Some challenges such as data protection, low scalability, high resource consumption must be addressed first before embracing blockchain for supply chain management. It is dissimilar from rest of the food supply system that are centralized whereas Blockchain is decentralized platform. There is wide scope in Blockchain for food supply chain. Blockchain has lots of potential for improving the trust concern, security paradigm, reliability and individual privacy in forthcoming years.

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