Food Supply Chains Using Block chain Technology: Jaggery Traceability use Case

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Abstract

Food provides nourishment and energy to all living beings and getting safe and uncontaminated food is the right of every individual. The food travels to the consumer from the producer in a supply chain. Supply chain is a network of actors to deliver food products to the consumer. The large number and heterogeneity of the stakeholders involved from different sectors, such as producers, distributors, retailers, customers, and quality checkers, render agricultural supply chain management one of the most complex and challenging tasks. Nowadays, the customers are unaware of the events happening to the supply chain items, which creates a lack of trust in their minds. So, the solution to this problem can be implemented efficiently using Blockchain technology. This paper is intended to explore transparency in the supply chain of food products by using Blockchain technology. It allows for decentralized data storage and provides immutability. The decentralized data storage makes it impossible for an unauthorized actor to tamper with the data. Our study in the food supply chains helped us to understand that more and more applications providing traceability and transparency in the food supply chain are being developed in many parts of the world. Though, there are certain hurdles in using blockchain technology for food supply chain management such as abiding by the policies and regulatory frameworks put in place by various governmental agencies and organizations and getting the actors in the supply chain educated with the technology. This paper discusses relevant methodologies to replace the ongoing methods employed by the industry to trace products in the supply chain, thus leading to a massive decrease in cost and efforts for the stakeholders and making products cheaper for the customers. The blockchain could also be deployed on cloud services to increase availability and reliability. The methodologies presented in this paper can be used by any food manufacturing industry that wants to track the products better and explore transparency in the supplychain.

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1. INTRODUCTION

The supply chains currently employed by food industries for supplying the products from the producer to the consumers have very complex nature, thus they do not providetransparencyandtraceability.Thesemethodscreate a lack of trust and confidence in the minds of the consumers while purchasing the food products. The consumers are also unsure if the food quality is preserved in the supply chain and that the food products are safe to consume. In the past two decades, the world has seen numerous foodborne illness outbreaks due to the consumption of contaminated products. Some of the recent incidents include South African listeriosis outbreak caused by the consumption of Processed Meat in the year 2017-18 resulting in 216 deaths, E. coli outbreak in Germany due to the consumption of fenugreek sprouts in the year 2011 resulting in nearly 4000 infections and 53 deaths, and the 2011 United States listeriosis outbreak due to the consumption of sweet melon leading to 30 deaths and a close to 150infections.

This has made various governmental agencies and health organizations think proactively in a way to avoid such outbreaks causing loss of lives, money and disrupting food systems. The agencies and organizations across the globe have therefore established regulations and food policies to reduce and possibly eliminate the foodborne illness outbreaks. For example, HACCP (Hazard Analysis and Critical Control Points) is a systematic approach to prevent physical, chemical or biological changes so as to avoid the contamination of the food products. This system was first developed in the 1960s by National Aeronautics and Space Administration (NASA) and Pillsbury to identify foodhazards and establish monitoring procedures for the supply chains. Due to the above mentioned food incidents and other pandemics such as the recent COVID 19, consumers are getting more concerned about the quality of food products that they are buying. The consumers want the food products that are unadulterated, quality compliant, and having certified origin even if they have to pay more to purchase these products. To provide traceability for food products, a number of traceability systems are developed which are centralized. In these systems,the data is stored and hence controlled by a single party/actor in the food supply chains who can change the data according to their wish thus making them untrustworthy. Considering the flaws in the traditional complex supply chains and those managed by a centralized storage, we can observe a noteworthy increase in the research on designing and developing traceable and transparent food supply chains. This research focuses on harnessing the capabilities provided by Blockchain Technology along with other technologies such as Internet of Things(IoT) and Radio-Frequency Identification(RFID) sensors. Though blockchain technology can help remove some of the major flaws encountered in the traditional supply chain management systems but it also possesses a whole new set of challenges for its adoption.

The potential of Blockchain technology to be used for a variety of purposes other than that of just managing cryptocurrencies and financial transactions was realized by the researchers in the mid 2010s. Since then a number of new applications have been developed. Some of these use cases include: tracking and verifying the ownership in real estates, tracing the food products in the supply chain, electronic voting and to trace the funds distributed by thegovernment for improving the infrastructure and to eradicate corruption.

These systems and others under development are already transforming many details of businesses, governments and the society in which we live. However these systems might also pose new challenges and threats that are undiscovered at this point of time. In general, these applications involving blockchain technology make data tampering impossible and create a trusted environment even in the presence of untrusted actors. In this paper, the authors try to provide a systematic review of the existing work done in transforming the food supply chains with the help of blockchain technology and also provide with the design and implementation of a prototype developed to trace organic jaggery in the food supplychain.

A. Brief Introduction to Blockchain

Satoshi Nakamoto, a pseudonymous person or a group of persons proposed a decentralized digital currency in their famous white paper[2][3], They referred to this currency as Bitcoin and it helped to avoid the double spending problem. This was arguably the first instance of using Blockchain technology.

Decentralization is at the core of Blockchain technology and it refers to an approach in which two nodes can carry out the transactions without involving a third party such as banks. This approach is known as peer-to-peer(P2P) exchange and can disrupt the existing systems that involve high reliability on third parties for storing data and processing transactions. Blockchain, as the name suggests is a chain of blocks where each block consists of a number of transactions linked by cryptography. The first block is called the genesis block and serves as the basis on which other blocks are added to form a chain of blocks. Each block contains a set of transactions,and a random value called nonce useful for mining the block along withthecryptographic hash of the previous block hence makingthechain tamper-proof. The transactional data present in the blocks is encrypted to improve security.

Every node in the network contains a copy of the ledger hence making the ledger distributed.

Whenever a block is mined by a miner which involves finding the cryptographic hash of the block, the block is communicated to each and every other node on the network, These nodes verify the block contents before adding it to their own ledger.

The state of the network where every node either agrees or disagrees to add blocks is maintained by the use of consensus protocols. As multiple nodes each maintain a copy of all the transactions, it becomes very difficult and nearly impossible for a malicious node to alter the content of the blocks. Even if it makes changes to its own ledger, these changes won't be accepted by other nodes on the network who verify the blocks. Maintaining a duplicate of transactional data makes it easy to achieve transparency andvisibility,

As far as the supply chain is concerned, this blockchain network may assure trust among users since centralized authority and intermediate actors are not present to tamper the data [7]. Adding to the advantages of blockchain, it can also verify smart contracts between the actors [8], record various activities happening in the supply chain. This proves beneficial in tracking the information regarding cash and time. The blockchain is further categorized as public, private, and consortium blockchains. According to requirements, any of these mentioned types of blockchain can be implemented in order to acquire advantages and increase the efficiency.

2. LITERATURESURVEY

The food chain is highly distributed and comprises numerous actors, such as farmers, transportation companies, manufacturers, dispatchers,distributors,wholesalers, retailers and consumers acting as the end user. [9]

The major process involved in a food supply chain are:

1.*Production*: All the major agricultural activities are performed in this phase. Farmers use organic fertilizers and organic seeds to harvest the crops.

2.*Processing*: The processing phase deals in transforming the raw materials into the finished goods. It can be followed with a packaging phase where each packaged product can be identified uniquely using a QR code or product identification code, which can be used in the further phases to add/ retrieve product-related information

3.*Quality Checks*: After the product is ready, quality checks are performed either internally or externally. The internal quality assurance team makes sure that the product is packaged according to the given specifications. In contrast, the external quality assurance team can be any food agency such as FSSAI, which checks if the product is quality compliant and also if the product is organic so that the product can be given an organiccertification.

4. *Distribution*: Once the product is ready and organic quality is verified, it is released for the distribution phase. It also involves the storage of food products under a specific range of

temperature and humidity for preserving the organic quality of the foodproducts.

5. *Retailing*: After the distribution phase, the food products are distributed to various shops/retailers .Retailers retail the product to the customers. The customers will verify the quality of the product using the systems described and then decide to purchase theproduct.

6. *Consumption*: Customers are the last actors of the chain. Customers can retrieve the product information and details about product storage using the QR code or the product identification code assigned to the product in the processing phase. The customer can then decide on purchasing the product if he/she finds it to be qualitycompliant.

Fig 1: General food supply chain

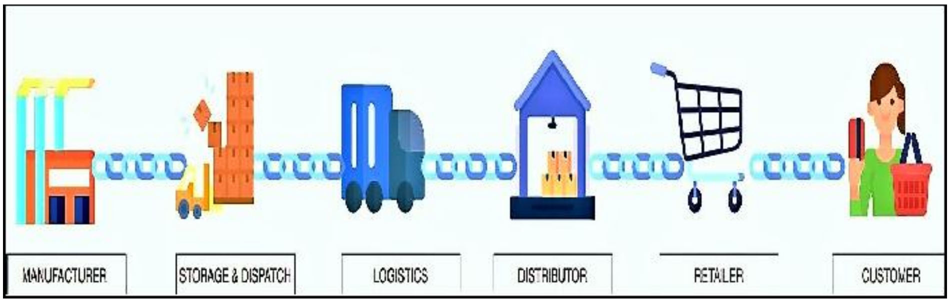


Fig. 1 gives a pictorial view of the traditional food supply chain. This system is unreliable because it does not allow for tracing of food products, and also, it is not trustworthy. Traditional methods of transferring goods in the supply chain were complex and time and cost ineffective[10]. The transactions occur in an untrusted environment thus lacking transparency and making auditing and monitoring difficult[11].According to an estimation, the cost of operating the supply chain contributes to two-thirds of the final product'scost.

Thus, it is possible to overcome the above- mentioned flaws and provide features such as transparency and traceability in the supply chain with reduction in cost and time required to trace the product back to itsorigin.

Early electronic supply chain traceability systems were centralized solutions based on centralized servers, databases, and all the data imported was entered manually or in a semi-automatic way. Gandino et al. (2009)[12] propose a solution using RFID tags to add the products in a fruit warehouse.The product-related data was updated using RFID tags and was stored on a central database. The data can be read from a Personal Digital Assistant(PDA) device provided to thepersonnel.

C. Cheng [13] proposed another supply chain traceability system which uses a centralized server for data processing and storage. This system marks the products with unique codes and stores information about them on a centralized database in Extensible Markup Language(XML) files, made available to every stakeholder. This implementation was efficient when the amount ofdatawas small so that the data can be processed without any additional requirements of computational resources.

These electronic traceability systems represent efforts to think differently than the traditional complex processes involved in the food supply chain.

A. Blockchain in Food Supply Chain:

The Blockchain technology has evolved over time in various sectors such as in real estate, in exchange for cryptocurrencies, and in gaming. It is being researched especially in supply chain management from 2016. After the evolution of this technology, there is evidence that applications for supply chain management were being developed using blockchain technology [14]. It is expected that blockchain in supply chain management will experienceanannualgrowthrateof87%andahikeof$3269 million in the span of 5 years from 2018 to 2023 [15].

As time evolved, blockchain technology was explored further by more fortune companies like IBM, Linux, Walmart and Kroger in order to create a project which will aim at building trust and bringing transparency in the group of untrusted entities (manufacturers, transporters, distributors, etc.) who are involved in the supply of food products [16]. Aiming to have a trusted and fault tolerant supply chain, Kroger and Walmart implemented blockchain technology in the Mexican mangoes' and Chinese porks' supply chain [17].

Starting from 2016, the world has experienced a drastic change due to blockchain technology in the field of supply chain management. Various large scale organizations like Intel and Louis Dreyfus Co had undertaken various projects for implementing this technology. Intel used Hyperledger Sawtooth, a platform where blockhains can be created and permissions can be managed, for developing blockchain for traceability of seafood[18]. Also sensors addedmore benefits in locationtracking and storing conditions. Similarly for the agricultural commodities' supply chain, Louis Dreyfus Co (LDC) had developed a blockchain based solution in collaboration with Dutch and French banks [19].

Further a new blockchain platform was introduced by Caro et al. which is termed as AgriBlockIoT. This blockchain platform is used for supply chains in agriculture. This system combines blockchain technology and devices of IoT for the purpose of distributing data of traceability of agricultural products. For the purpose of testing the above solution,

Hyperledger Sawtooth and Ethereum blockchain based platforms are used. After testing, comparison in terms of efficiency was found and the conclusion was that the Ethereum blockchain platform performed efficiently in the CPU usage functionality, in latency and also in network usage as compared to Hyperledger Sawtooth blockchainplatform.

The World Wildlife Fund (WWF) implemented a project named as "Bait-to-plate". It mainly focuses on the traceability of tuna in New Zealand and uses RFID technologies for fish tagging and an Ethereum-based blockchain. This assures tamper-proof tracing of tuna fish which avoids illegal events happening during the supply chain. It helps the fishermen in registering their catched fishes on the blockchain using RFID e-tagging and by scanning their catched fishes [20].

Downstream beer, a company in the field of beer uses blockchain technology in order to bring transparency in the supply chain of beer which further provides transparency in its ingredients and brewing methods. Consumers are redirected to a website containing information about the supply chain of the purchased beer with the help of QR code available on thebottle.

Furthermore, ripe.io has implemented a food supply chain using blockchain named as Blockchain of Food [21], which helps in preserving food quality throughout the supply chain starting from production to the end consumer. Maersk's drive venture arm held a round of seed funding where Ripe.io successfully managed to raise$2.4 million.

3. PROPOSED SYSTEM

This system on Supply Chain Traceability for Organic Jaggery is built from the perspective of both producers and customers of the Supply Chain for Organic Product (Jaggery). It aims to provide traceability in the Supply Chain by displaying the current status of a particular product at any time. This system allows the producer to add new orders on the blockchain and customers to trace the product. This product also enables the other actors to update the status of the product. This project can be used by any organic manufacturing industry that wants to better track the products and bring transparency in the supply chain while saving costs and manual work. Various actors involved in the supply chain are Manufacturers, Dispatcher, Distributors, Wholesalers, Retailers, and Customers. The customers are unaware of the events happening to the items in the supply chain thus creating a lack of trust in the minds of the customers. The customers are also unsure if the product is truly organic. This project is intended to bring transparency in the supply chain of Jaggery by using Blockchain Technology (Multichain) which allows for decentralized data storage and provides immutability. The decentralized data storage makes it impossible for an actor to change an item's details without having proper authorization.

This project is expected to replace the ongoing methods employed by the industry to trace products in the supply chain, thus leading to an immense decrease in cost and efforts for the producers and making the products cheaper for the customers. This project will also provide the customers with surety of product being fresh and organic.

4. DESIGN

The major User classes in System would be:

1. Producer or Manufacturer: Producer can accept the order, verify organic quality and update the status of order.

2. Customer: Customers can view all the transactions related to the product by querying Order ID/ Product ID.

3. Dispatcher: The dispatcher will accept product from the manufacturer and transfer it to transportation.

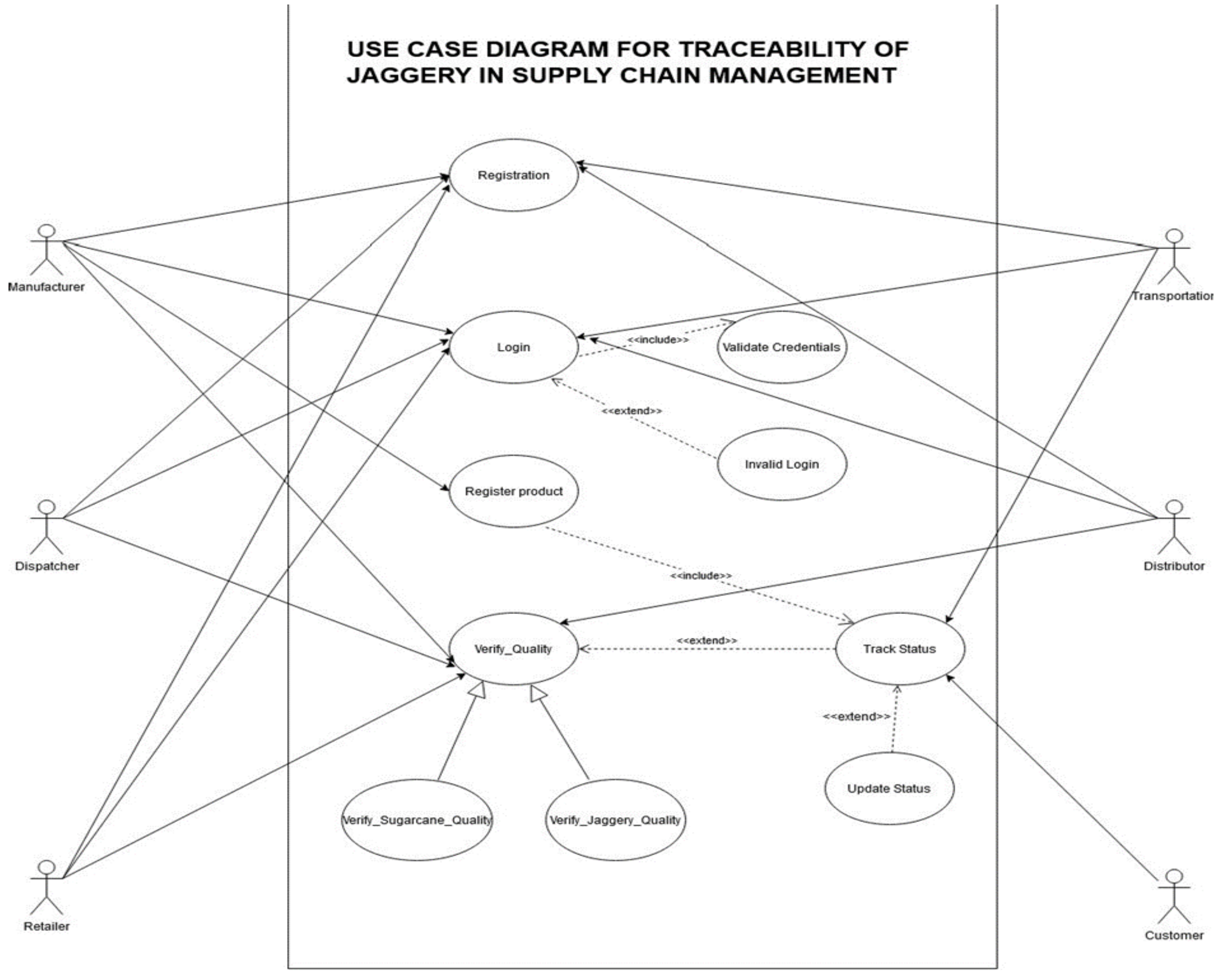
4. Distributors: Receive a product from the producer/manufacturer and can sell it to wholesalers.

5. Wholesalers: Receive a product from the dispatcher and can sell it to retailers.

6. Retailers: Receive a product from the distributor and sell it to customers.

7. Transportation Team: Deliver the product from producer to the customer at various stages(entities) (if required).

Fig 2:UseCaseDiagram



Following are the major functional requirements of the project. Figure 3 represents the sequence diagram for sample case i.e trace product status.

Trace Product Status -The product will move through various phases of the Supply Chain. Each product will have a unique product ID which will serve as the primary attribute of the product, along with several other attributes like price, raw materials, producer’s details, etc. As the product moves through different actors in the Supply Chain, the transactions will be recorded on the blockchain along with the date and time of the transaction. The product can be traced by all the stakeholders.

Add Product-The system allows the producer to add new products and enter them in the Supply Chain. The addition of a new product will lead to the deployment of a new smart filter on the blockchain where all the transactions of the product will be recorded.

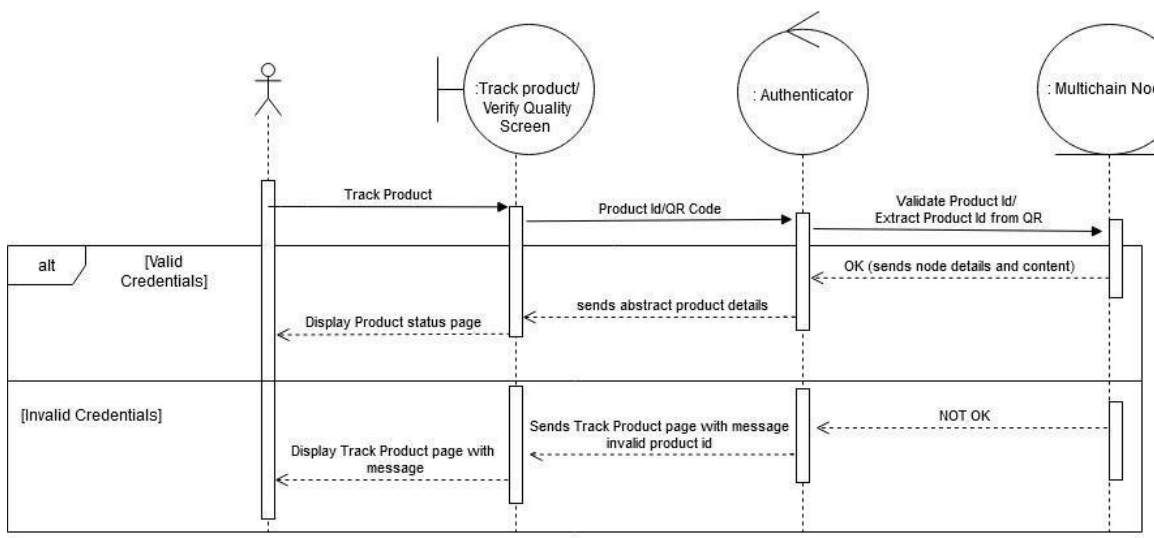
Update Status-The actor will be able to update the product's status and transfer it to the next actor in the Supply Chain. The actor will verify quality and then send it to the next actor if the product is quality compliant.

Actor Registration-Actors except Customers need to be registered to be able to perform functions in the application.

Actor Sign-in-Actors except Customers need to be signed in into the application to be able to perform functions in the application.

Actor Update Profile-Actors except Customers need to be able to update profile.

Fig3: Sequence Diagram for Trace Product Status

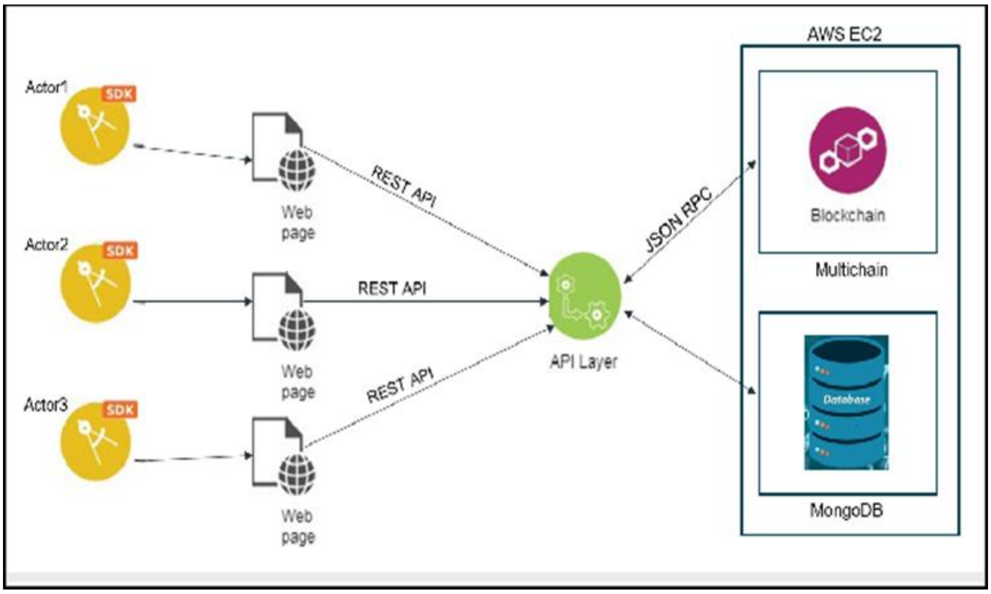


5. ARCHITECTURE ANDIMPLEMENTATION

The components of the system involve:

1. The backend i.e. business logic will be developed using JavaScript language on the Multichain framework which is based on Blockchain technology.
2. The frontend i.e. user interface will be developed using HTML, CSS, JavaScript, and use of any particular frontend framework like AngularJS, ReactJS.
3. The nodes representing the various actors will be deployed on AWS Cloud Services to ensure high availability and fault-tolerant working of the application.

Fig 4: Architecture



Actors or systems interact with the blockchain through web pages as shown in above Fig. 2. Web pages designed further interact with the API Layer in order to record or retrieve transactions on the blockchain. Tokens are implemented for security purposes in the interaction between nodes and blockchain. Business logic is implemented along with the API in the middle layer. A database implementation such as MongoDB stores user information and helps in authenticating and authorizing users.

Web pages are implemented using HTML, CSS and Javascript. Javascript is a dynamic computer programming language. It is a lightweight, interpreted programming language which is designed for creating network-centric applications. AJAX (Asynchronous JavaScript and XML) calls are used at multiple points in order to send and retrieve data from a server asynchronously without interfering with the display and behaviour of the existingpage.

REST APIs are implemented using NodeJS and ExpressJS (JavaScript-based platform). REST (REpresentational State Transfer) API is preferred since it is lightweight, highly scalable and maintainable. Sincethisweb application has to handle more than one pair of request-response to complete, session management is implemented in order to track its current status. Typically, a session is started when a user authenticates their identity using login credentials. API plays an important role in interacting with the multichain node in order to send and retrieve data. Multichain-node library is used for building native Javascript clients in this web application.

Permissioned blockchain is built on the Multichain platform. Multichain is an extended open-source fork of Bitcoin which can be used to launch custom blockchains, both private and public. It offers a well-selected set of features and enhancements targeted at enterprise and business users [22]. MongoDB is implemented for authenticating users. It includes various actors' details, login credentials and sessions. MongoDB is a cross-platform, document oriented database that provides, highperformance,highavailability,andeasyscalability.

Blockchain with multichain is deployed on Amazon Web Services (AWS) cloud. JSON-RPC is a stateless, light-weight remote procedure call (RPC) protocol which helps in interaction between API layer and multichain nodes. The API layer is deployed in a public subnet in Amazon AWS Virtual Private Cloud(VPC) and is accessible to the Internet using the assigned IP address. The Multichain node is deployed in a private subnet and is accessible to the internal resources of VPC only, thus making the multichain node inaccessible to the Internet directly. The Multichain node also sits behind a load balancer called AWS Elastic Load Balancer(ELB) to account for the change in traffic loads coming to the node and to provide higher availability and resiliency. If the load surpasses a defined threshold limit, a new Multichain node is set-up at the runtime and traffic is distributed between the twonodes.

We need to create a chain on the Multichain Node using an identifier as a chain name and can create any number of streams in that chain. MultiChain streams enablea blockchain to be used as a general purpose append-only database [22]. It provides a natural abstraction for blockchain use cases which focus on general data retrieval, timestamping and archiving. Multichain stream allows us to store a sorted list of JSON objects composed of key-value pairs. Multichain streams include one or more publishers, one or more keys, some data that can either be in JSON, text or binary format. These transactions are stored in a block and on the successful addition in the block, information regarding the object's transaction and block is included.

In our prototype, one stream called product-data is created to store data. Data can be queried from streams using JSON-RPC calls. Three major functionalities implemented using streams such as add product, update product status and trace product. Alongside this, the manufacturer can also see all the products added by them so they don't have to keep a track on Product ID. In add product the data is added to the streams in JSON format by providing the product code as key. In Update Product status functionality, product data can be updated only by the authorized actor i.e., the actor possessing the product and a new JSON object is published to the product-data stream with the same key as that of add-product functionality. While tracing products, the customer can enter the unique product code to fetch all the details related to the product. While tracing, the array of objects with product code as key is retrieved from the product-data stream and these objects are combined to create a summarized object containing all the details of the product and this JSON object is sent to the Front-End using REST API. To keep track of the products added by a manufacturer, a JSON-RPC call is made to retrieve all the data from the stream and then the manufacturer field of each object is checked to see if the logged in actor is the manufacturer of the product. The data consisting of Product ID, Product Name, CurrentOwnerand Current Location from each object is combined in an array of objects and is then sent to the User Interface.

6. RESULT

Fig 3: Register Page

Fig 4: Login Page

Fig 5: Add Product by Manufacturer

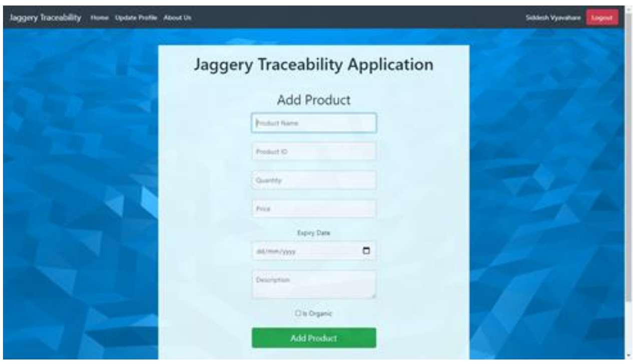


Fig 6: Update Product Status by Actor 1

Fig 7: Update Product Status by Actor 2

Fig 8: Trace Product

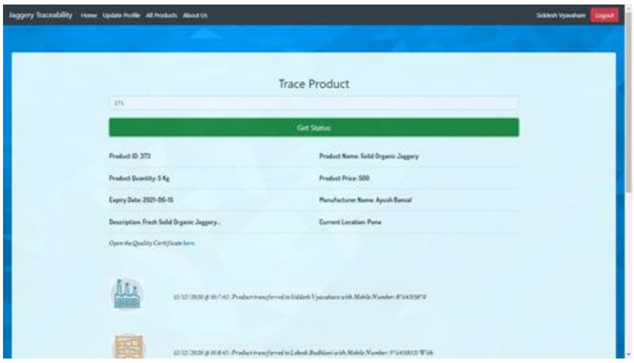
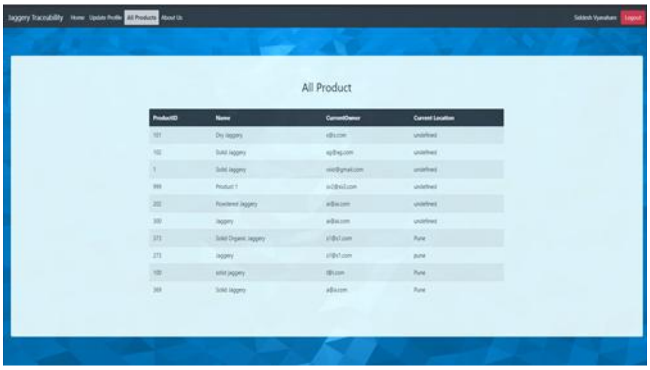


Fig 9: All products added by Manufacturer with current Owner, Location



7. CONCLUSION AND FUTUREWORK

The problems that exist in the traditional supply chains can be effectively solved with the help of Blockchain technology along with other technologies. The solution described in this research paper provides transparency and traceability in the supply chain and creates a trusted network even in the absence of trusted actors. The solution when implemented can reduce the time and cost associated with tracing the product back to its origin in case of foodborne illness outbreaks. This solution can also develop trust in the minds of customers and increase the company sales if the customer understands the way in which Digital Ledger Technology functions and stores the data in a tamper-proof environment, thus making customers aware of the events happening to the product in the supply chain. In general terms, this article can help to replace the ongoing methods employed by the industry to trace organic food products in the supply chain, thus leading to an immense decrease in cost and efforts for the producers and making the products cheaper for the customers. In future work, we try to eliminate the use of MongoDB for storing users' information by storing the data on the Multichain node in a decentralizedmanner.

In Future of this research, implementation of IoT smart sensors will be included in the supply chain commodities to verify constraints such as temperature, humidity used for quality preservation.

REFERENCES

[1] Kamilaris, Andreas, Agusti Fonts, and Francesc X. Prenafeta-Boldύ. "The rise of blockchain technology in agriculture and food supply chains." *Trends in Food Science & Technology* 91 (2019): 640-652.

[2] Chang, Shuchih E., and Yichian Chen. "When blockchain meets supply chain: A systematic literature review on current development and potential applications." *IEEE Access* 8 (2020): 62478-62494..

[3] Nakamoto, Satoshi. "Bitcoin: A peer-to-peer electronic cash system." Decentralized Business Review (2008): 21260.

[4] Crosby, Michael, et al. "Blockchain technology: Beyond bitcoin." *Applied Innovation* 2.6-10 (2016): 71.

[5] Neisse, Ricardo, Gary Steri, and Igor Nai-Fovino. "A blockchain-based approach for data accountability and provenance tracking." Proceedings of the 12th International Conference on Availability, Reliability and Security. 2017.

[6] White, Gareth RT. "Future applications of blockchain in business and management: A Delphi study." *Strategic Change* 26.5 (2017): 439-451.

[7] Casey, Michael J., and Pindar Wong. "Global supply chains are about to get better, thanks to blockchain." *Harvard business review* 13 (2017): 1-6.

[8] K. Toyoda, P. T. Mathiopoulos, I. Sasase, and T. Ohtsuki, ‘‘A novel blockchain-based product ownership management system (POMS) for anti-counterfeits in the post supply chain,’’IEEE Access, vol. 5,pp. 17465–17477,2017.

[9] Caro, Miguel Pincheira, et al. "Blockchain-based traceability in Agri-Food supply chain management: A practical implementation." *2018 IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany)*. IEEE, 2018.

[10] Tripoli, Mischa, and Josef Schmidhuber. "Emerging Opportunities for the Application of Blockchain in the Agri-food Industry." *FAO and ICTSD: Rome and Geneva. Licence: CC BY-NC-SA* 3 (2018).

[11] Lierow, Michael, Cornelius Herzog, and Philipp Oest. "Blockchain: The backbone of digital supply chains." *Oliver Wyman* (2017).

[12] Gandino, Filippo, et al. "On improving automation by integrating RFID in the traceability management of the agri-food sector." *IEEE Transactions on Industrial Electronics* 56.7 (2009): 2357-2365.

[13] Tse, Daniel, et al. "Blockchain application in food supply information security." *2017 IEEE international conference on industrial engineering and engineering management (IEEM)*. IEEE, 2017.

[14] Tribis, Youness, Abdelali El Bouchti, and Houssine Bouayad. "Supply chain management based on blockchain: A systematic mapping study." *MATEC Web of Conferences*. Vol. 200. EDP Sciences, 2018.

[15] Chang, Yanling, EleftheriosIakovou, and Weidong Shi. "Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities." *International Journal of Production Research* 58.7 (2020): 2082-2099.

[16] Manski, Sarah. "Building the blockchain world: Technological commonwealth or just more of the same?." *Strategic Change* 26.5 (2017): 511-522.

[17] Kamath, Reshma. "Food traceability on blockchain: Walmart’s pork and mango pilots with IBM." *The Journal of the British Blockchain Association* 1.1 (2018): 3712.

[18] N. NasurudeenAhamed, Karthikeyan P, S.P.Anandaraj, 4Vignesh R,SeaFood Supply Chain Management Using Blockchain.
Available:
https://www.researchgate.net/publication/340886609_Sea_Food_Supply_Chain_Management_Using_Blockchain

[19]E. Hofmann, U. M Strewe, and N Bosia, Supply Chain Finance and Blockchain Technology: The Case of Reverse Securitisation. Cham, Switzerland: Springer Nature,2018.Available:http://link.springer.com/10.1007/978-3-319-62371-9

[20] Balfegó Group. (2017). Retrieved fromhttps://balfego.com/ca/trasabilitat/

[21] Raja Ramachandran and ripe.io team. “The blockchain of foods .” https://www.ripe.io/media/2019/6/20/the-blockchain-of-food, Oct 23,2017

[22] Greenspan, G. (2015). MultiChain Private Blockchain. Available online at: https://www.multichain.com/download/MultiChain-White-Paper.pdf