Food-Health-Chain: A Food Supply Chain for Internet of Health Things Using Blockchain

Puja Das, Amrita Haldar, Moutushi Singh, Anil Audumbar Pise, and Deepsubhra Guha Roy

1 Introduction

AI, the Internet of things, and blockchain are all part of a recent change in thinking in engineering and technology. Mobile communication tools, IoT, intelligent networks, predictive analytics, AI, and blockchain, have given the healthcare sectors a new perspective and perspective. These digital interactions are merging to reshape the healthcare industry. Blockchain technology is a game-changing invention that is helping to design a new age. In 2008, a person named Satoshi Nakamoto created "Bitcoin", which is a decentralized digital money based on blockchain technology [1]. Blockchain is a distributed ledger that records digital transactions. If data is entered and stored in this network, it is visible and available to everybody, but it cannot be modified [2].

P. Das
Department of Computer Science, HMM College for Women, Dakshineswar, Kolkata 700035, India

A. Haldar
Department of Computer Science and Business Studies, IEM, Kolkata 700091, India

M. Singh
Department of Information Technology, IEM, Salt Lake, Kolkata 700091, India
e-mail: moutushi.singh@iemcal.com

A. A. Pise
Department of Data Science and Machine Learning Computer Science, University of the Witwatersrand, Johannesburg, South Africa
e-mail: anil@siatik.com

D. Guha Roy (✉)
IEM Centre of Excellence for Cloud Computing and IoT, Department of CSE (AIML), Institute of Engineering and Management, Kolkata 700091, India
e-mail: roysubhraguha@gmail.com

J. K. Mandal et al. (eds.), *Proceedings of International Conference on Network Security and Blockchain Technology*, Lecture Notes in Networks and Systems 738,
https://doi.org/10.1007/978-981-99-4433-0_30

Table 1 Comparative analysis of different distributed framework

	Transaction output	SC language	Database	Access	Consensus
Ethereum	Low	Solidity	Level DB	Using SC	PoW
Hyperledger	High	Java, Jscript, Python	Level DB	ACL	PoET, PBFT
Bitcoin	Low	Python	Web	Network	PoW

In other words, data remains unchanged and is temper resistant, once it is posted to the decentralized network. Because it is a distributed ledger, it has fewer possibilities of collapsing than a centralized system. From a commercial standpoint, blockchain is every product with its unique means of tracking, recording, and verifying information. Blockchain was first utilized as the core frame technology in cloud storage for any e-commerce [3]. This technology is eligible to be used in supply chain systems as a result of all of this. We'll go through some of the most important aspects of blockchain technology here:

- **Decentralized:** The primary characteristic of blockchain is that all data can be recorded, stored, and updated in a distributed manner, with no need for a single node.
- **Transparent**: Each node in the blockchain system transparently records data, and this transparency is maintained when the data is updated, which is why blockchain is trusted [4].
- **Immutable:** In the blockchain, all published data will be maintained indefinitely, unless and until someone can seize control of more than 51 percent of the nodes in the same amount of time.

This article will look at how supply chain companies may be benefited from this technology and how it can help them solve challenges (Table 1).

1.1 Motivation and Contribution

To make living easier, the globe has been transformed into a digital environment. The Internet of things (IoT) is the most excellent platform for connecting every tiny device or object to a large network. Because we are in an IoT network, everyone knows everything, and IoT is a little bit expensive; when a person transfers data to communicate, it becomes public. Every transaction is significant to a specific individual, yet this information, whether it is money, personal information, or health data, attracts hackers and intruders [5]. To address this, we are attempting to create a safe solution based on blockchain. The following are the contributions:

- We propose a recommended-based distributed, secure food supply chain for healthcare using the Internet of health things (IoHT).
- We presented a case study considering two different health issues and how they can be benefited from the proposed food supply chain plan.

- A smart contract-based approach is also applied to safeguard information and data.
- We offer proper food recommendations in a distributed, transparent, immutable, and secure environment.

1.2 Organization of Paper

This article is arranged as follows: Sect. 2 provides the literature review and a theoretical foundation of blockchain, among other topics. In Sect. 3, traditional supply chain model for farming is defined. The suggested system model is presented in Sect. 4. The experimentation outcomes for our suggested method in Sect. 5. Finally, Sect. 6 concludes this study.

2 Literature Survey

Satoshi Nakamoto published the first white paper on Bitcoin in 2008. The white paper described peer-to-peer electronic cash known as "Bitcoin" that allowed online payments can be made without the use of an intermediate such as a bank or a sovereign government [6]. Blockchain is the ground-breaking technology that underpins Bitcoin. Bitcoin is only one of the tens of thousands of apps that make use of distributed ledger technology. Blockchain implements a decentralized ledger with an infrastructure of emulated databases that are synchronized via the Internet and visible to anyone within the network, compared to existing databases with a central authority or administrations (like banks and public sector accountants) that handle all transactions. A blockchain network can be open to the public and available to anybody globally, or it can be private with limited membership (Fig. 1). Ethereum is another blockchain technology (edition 2.0). Vitalik Buterin was the one who came up with the idea [7].

It is built in such a manner that anybody with a basic understanding of computers may create and deploy decentralized apps on the blockchain. Its own currency, "Ether", and an Ethereum Virtual Machine (EVM). Ethereum has its own computer program, dubbed "solidity", that is used to code the apps. Aside from that, Ethereum allows you to create a "smart contract", which is a self-contained digital system with built in code that controls transactions between users on the blockchain. EVM and Ether are used to operate these transactions [8]. We can also use the blockchain platform that enables IoT devices. In a smart city, blockchain will also aid in the development of an authentication scheme that connects blockchain technology with smart devices to create a secure communication platform. Blockchain may be used in a variety of supply chain management systems to establish a decentralized network that provides transparency, security, neutrality, and dependability to all supply chain activities. Medium.io is a corporation that has developed a method for regulating the

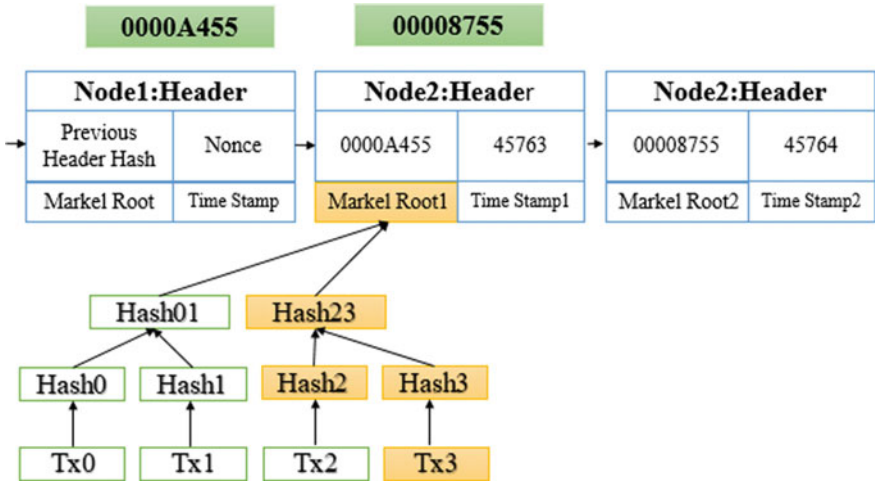

Fig. 1 Blockchain internal structure and its advantage

efficient operation of the medicine industry by integrating IoT sensor devices with blockchain technology [9]. The healthcare supply chain plays a critical role in getting food from farmers to people's plates as per patients' requirements. The major cause of inefficiency in the healthcare supply chain is a lack of mutuality and cooperation among the client or patient. As a result, a sound inventory management system is responsible for effective production, handling, distribution, and marketing, fulfilling consumer expectations, and delivering a high-quality healthcare industry [10].

3 Traditional Supply Chain Model for Healthcare

The conventional healthcare supply chain was simpler: It was continuous, and generally, it is used for business with firms that were quite close to you. The traditional healthcare supply chain consists of some units, namely develop, plan, medicine source, create, deliver, and support. Every module has its own importance, but this supply chain faces various challenges. On the other hand, we have different type of patients and their variations of food requirements. The same kind of food is provided to each patient in the general system, which is not recommended. For that healthcare industry needs a digital and secure healthcare system that must be flexible and linked.

Figure 2 shows a general supply chain at the association level within the framework of a whole supply chain setup. Every firm is located in a layering system and fits a minimum supply chain. It generally has various and changeable suppliers and customers at a similar point in time and over time [10]. The supply chain management monitors the multi-stage supply chain organization that contains farmers, brokers or middle man or agents, processing companies, and end users [11].

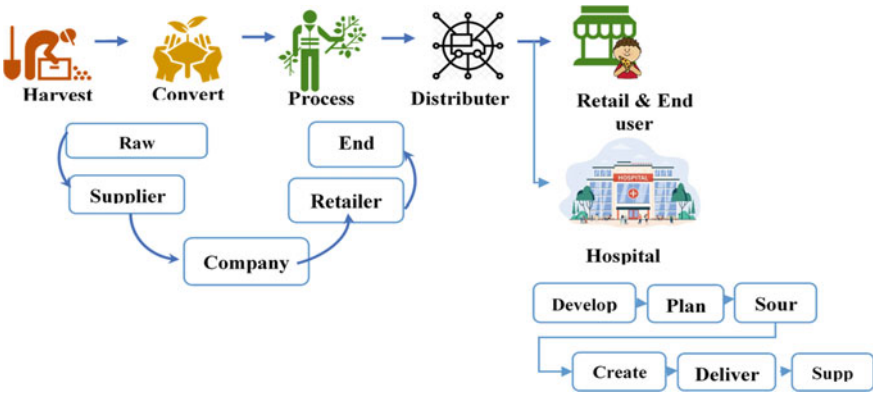

Fig. 2 Traditional healthcare system with food generation

4 System Design

In built-up systems, the supply chain is made up of a succession of schemes or modules that include people, existing resources, awareness, processes, financial agreements, and communications that make it easier to get a product from the manufacturer to the end-user or consumer. It isn't easy to get a comprehensive picture of all connections within an extensive health care-chain system because materials are stored in various locations in a typical supply chain system. As a result, the patients and end-user only have limited access to the entire system. As a result, there is a lack of openness and trust among the institutions' members. Presently, health care-chain, a blockchain-based supply chain for providing the best food as per requirement, is being announced.

In future, this object will be a decentralized distributed organization that employs blockchain technology to assemble, stock, and complete essential creation information for each product throughout its entire cycle. This dispersed block of data may potentially establish a secure, shared record of transactions for each production, as well as precise product data. Accumulating raw material, system communication mode, and user interaction mode are the three key components of the system model.

4.1 Raw Materials and Quality Assurance

Figure 3 depicts a possible future application of blockchain in the supply chain for industrial systems. The suggested solution involves a federated distributed organization that employs blockchain to collect, store, and retrieve crucial creation data throughout each invention's product lifecycle. This creates a secure, community record of each creation's dialog, as well as accurate product material. Many actors, including producers, suppliers, manufacturers, distributors, sellers, and eventually

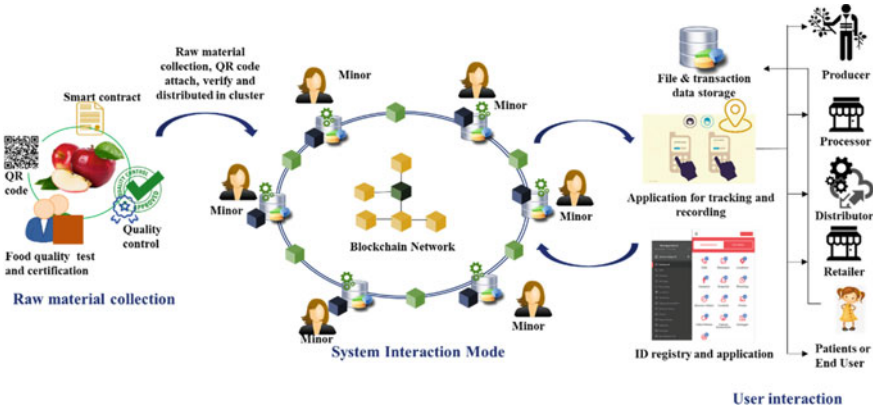

Fig. 3 Proposed blockchain-based food supply chain for healthcare system

the end customer, control how a production or raw material evolves during its life cycle.

4.1.1 Interaction With the User

The interactive query mode is divided into two parts: The first contains a store, trace, and application, while the second includes the conventional portion, which includes producers, processors, wholesalers, retailers or healthcare units, and customers or patients. The first component, on the other hand, is primarily concerned with system interaction. Those data are mostly captured and verified from the blockchain network, and they are stored and traced here. The second component is explained further down.

4.1.2 Production

These digital profiles store the most important information about the patients. This information includes things about which patients need what. Then, after completing a digital contract (smart contract) that is maintained on the blockchain, a new job is begun between the farmers and the intercessors or farming dispensation businesses, where the product is substituted. Figure 4 shows a blockchain framework.

To carry out the complete suggested process and distribution of health care—food goods from genesis to end customers, chain management systems entail many entities. As a result, tracking and tracing the entire process are complicated. To ensure total traceability, we keep track of each trade transaction from start to finish, adding the product's unique identity and lot number to each subsequent transaction and recording the hashes to keep hash network one going.

The procedural data is kept in the healthcare chain to maintain the hash chain. The data hashes are stored in the Ethereum blockchain, which circumvents the limitation.

Fig. 4 Blockchain-based food transfer of patients

An access control method is used to create or decrypt messages from the blockchain, which guarantees the network's privacy and secrecy. The implementation of security techniques ensures that only the authorized user operates. Furthermore, each smart contract function may only be conducted by certain entities. Unauthorized individuals are not permitted to carry out any tasks. The entity registration process is represented by Algorithm 1, in which several supply chain entities are registered in the system and interact via smart contracts.

4.1.3 Procurement

The procurement center is now complete. To appreciate agricultural dispensation enterprises, the digital form of the development is efficient by supplying information linked to warehousing and seed transference from farmers.

4.1.4 Processing

Once the doctor has received the food routine, they will begin circulating.

Algorithm 1
Transparent Food Supply.

Input: *Add_node*, *msg.sender*, *node* + +
Output: Transparent Food Supply
INITIALIZATION
Add_node
Add Entity **//Start Identifying**
If msg.send() == **Authority** then entity initials
identity ← *user_name*
endif
REGISTRATION
If msg.send() = *APPROVED then*
Update node value node++
endif
ADD NEW NODE
New_node ← APPROVED user
if make_tran() = APPROVED then
Update node value node++
endif
endif
make_tran() **// Make Transaction**
REGISTER SUGGESTION
If msg_send++ *s an element from Approval list*
Addsuggestion() *Satisfied Ratings*
suggestion ++
else
Revert contract and presentation error
Savesuggestion++
Sendsuggestion()
Requggestion()
Find Suggestion()

4.1.5 Distribution as Food Requirements

Following the receipt of shipments from farming processing firms, information on the quality, loadings, logistics, and delivery is continuously updated on blockchain at precise breaks by the suppliers. It will keep track of all supplier actions when delivering products to retailers.

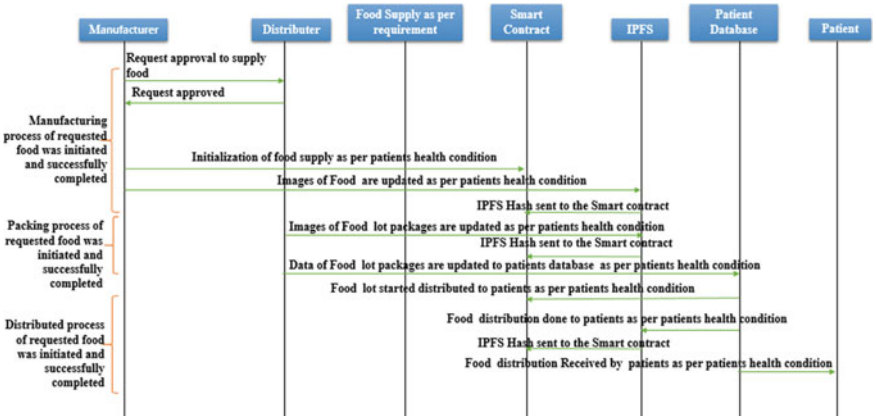

Fig. 5 Sequence diagram presentation interactions between the health entities with smart contract

4.1.6 Healthcare System

When merchants get farming bags, they roughly gather all of the information by reading the tags attached to the food packages. Because all of the information about food distribution is stored in a digital sketch on the blockchain, anyone with a blockchain-related programmer may access it.

4.1.7 The Patient or Client

At this point, the final user receives their product and provides comments. Figure 5 depicts sequence diagram that presentation interactions between the health entities with smart contract.

5 Experimental Analysis

We are trying to segregate the foods based on the health hazards the food contains, by implementing a QR code for every batch of product. The QR code is an effectual transmission medium for information. QR codes are very popular in applications like product traceability, advertising, mobile payment, passport verification, and a lot more. Figure 6 represents the QR code in which we have stored the necessary details of a particular batch of shipping cases which contains harvested agricultural products which are clustered into batches based on the patient's food types, for example, food like sugarcane, honey, sweet potato (potato family products) can be marked with its health benefits/hazards. The product details like "Product ID", "Product Code", "Product Manufactured Date", "Product Unit of Measure", "Product Price", and

Fig. 6 Represents QR code of a product

PID:1010, PCode:Potato,PMFGDate:30122021,PPrice:15RS,PUOM:KG,HHTYPE:DIAB	PID:4110, PCode: Red lentil, PMFDate:30122021,PPrice:40RS,PUOM:KG,HHTYLE:URIC

Fig. 7 Scan output of QR code

"Health Hazard Type" are embedded in the QR code, which can be tracked from any node in the supply chain. The QR code can be encrypted using AES-265 for further security, with the help of custom logic and keys (Fig. 7).

5.1 Test Run

We selected mainly two food items to test track our application: (1) potato and (2) red lentil. Both potatoes and red lentil are sourced from local farmers. The products are then shifted to a warehouse after gathering them from the farms and are sold at the farmer's market. For the simulations, an open-source blockchain technology, namely Ethereum, is employed. We executed this as a Web service (SaaS) on Remix Integrated Development Environment (IDE), Ganache, and Meta mask and generated the QR codes, which contains all the relevant information related to the product, to evaluate the performance of a blockchain-based supply chain network. Remix makes it easier to write, execute, and test smart contracts. Figure 8 shows the cost unit intake by the proposed system.

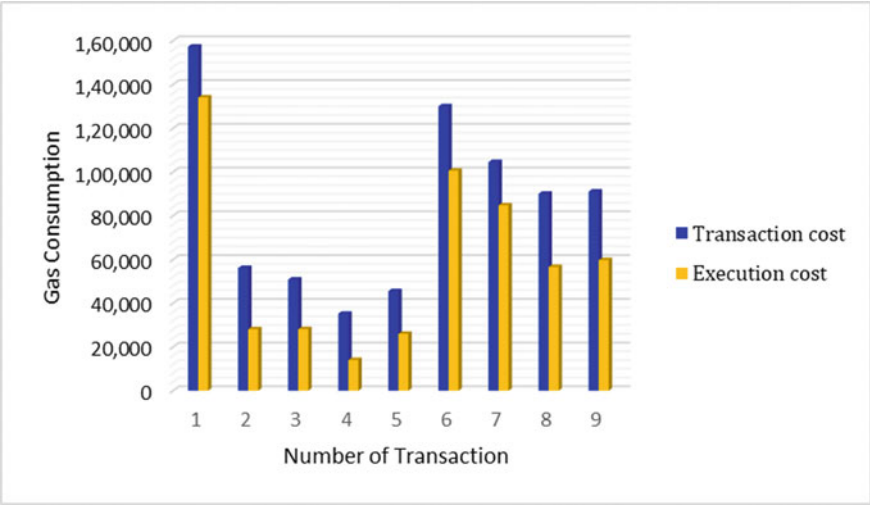

Fig. 8 Cost unit intake by the proposed system

We imitated the production in the above-mentioned farms in the decentralized application platform to reproduce the entire plot of the real-world food manufacturing system. For both potatoes and red lentils, each of them has hundred kilograms of product are accumulated into the same block and blockchain consisting of two main blocks "the genesis block and the hash of genesis block" which is generated for each individual batch. Since each batch of product made it to the farmer's market via the distribution center, each batch is processed in such a way that they have three blocks in the chain. The "genesis block" is the "hash of the genesis block" when it was sent to the distribution center and the "hash of the block" from the distribution center after it reaches the agriculturalist's marketplace.

6 Conclusion and Open Challenges

Blockchain technology can potentially change many existing traditional systems into more secure, decentralized, transparent, and collaborative systems while empowering individuals. We analyzed some of the critical aspects of blockchain technology and explored possible application fields in this paper. The article's attention was shifted to the applicability in healthcare specifically Internet of health things (IoHT)-based supply chains. A blockchain-based health supply chain was presented. This technique proves a smarter option for the health system for food suggestions. This degree of input may help this industry enhance its technology and food suggestions for individuals. Smart contracts may be integrated into this system to increase data integrity.

As part of ongoing efforts to improve the effectiveness of healthcare supply chains, we want to expand the recommendation system to achieve end-to-end transparency and verifiability of medication usage in the hereafter.

References

1. Nguyen DC et al (2021) Blockchain and AI-based solutions to combat coronavirus (COVID-19)-like epidemics: a survey. IEEE Access 9:95730–95753
2. Guha Roy D et al (2021) A blockchain-based cyber attack detection scheme for decentralized internet of things using software-defined network. Software: Practice and Experience 51(7):1540–1556
3. Liu P et al (2020) Investment decision and coordination of green agri-food supply chain considering information service based on blockchain and big data. J Clean Prod 277:123646
4. Roy DG et al (2019) QoS-aware secure transaction framework for internet of things using blockchain mechanism. J Netw Comput Appl 144:59–78
5. Sanal Kumar KP et al (2021) Security and privacy-aware artificial intrusion detection system using federated machine learning. Comput Electric Eng 96:107440
6. Barbosa MW (2021) Uncovering research streams on agri-food supply chain management: a bibliometric study. Global Food Secur 28:100517
7. Lee G-S et al (2020) A blockchain system for history management of agrifood. J Korea Acad Industr Cooper Soc 21(10):159–165
8. Das P et al (2021) Impact of blockchain-based cyber security implementing industry 4.0. Industry 4.0 Interoperability, Analytics, Security, and Case Studies. CRC Press, 13–34
9. Balasubramanian S et al (2021) A readiness assessment framework for Blockchain adoption: a healthcare case study. Technol Forecast Social Change 165:120536
10. Kuo T-T et al (2021) Benchmarking blockchain-based gene-drug interaction data sharing methods: a case study from the iDASH 2019 secure genome analysis competition blockchain track. Int J Med Inform 154:104559
11. Das P et al (2023) Block-a-city: an agricultural application framework using blockchain for next-generation smart cities. IETE J Res 2023:1–11