Fusion of Blockchain-IoT network to improve supply chain traceability using Ethermint Smart chain: A Review

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Received November 8, 2021; revised May 31, 2022; revised July 19, 2022; revised September 5, 2022; accepted October 4, 2022; published November 30, 2022

Abstract

In today's globalized world, there is no transparency in exchanging data and information between producers and consumers. However, these tasks experience many challenges, such as administrative barriers, confidential data leakage, and extensive time delays. To overcome these challenges, we propose a decentralized, secured, and verified smart chain framework using Ethereum Smart Contract which employs Inter Planetary File Systems (IPFS) and MongoDB as storage systems to automate the process and exchange information into blocks using the Tendermint algorithm. The proposed work promotes complete traceability of the product, ensures data integrity and transparency in addition to providing security to their personal information using the Lelantos mode of shipping. The Tendermint algorithm helps to speed up the process of validating and authenticating the transaction quickly. More so in this time of pandemic, it is easier to meet the needs of customers through the Ethermint Smart Chain, which increases customer satisfaction, thus boosting their confidence. Moreover, Smart contracts help to exploit more international transaction services and provide an instant block time finality of around 5 sec using Ethermint. The paper concludes with a description of product storage and distribution adopting the Ethermint technique. The proposed system was executed based on the Ethereum-Tendermint Smart chain**.** Experiments were conducted on variable block sizes and the number of transactions. The experimental results indicate that the proposed system seems to perform better than existing blockchain-based systems. Two configuration files were used, the first one was to describe the storage part, including its topology. The second one was a modified file to include the test rounds that Caliper should execute, including the running time and the workload content. Our findings indicate this is a promising technology for food supply chain storage and distribution.

Keywords: Ethereum, Ethermint, Inter Planetary File Systems (IPFS), Lelantos, Smart chain Smart Contract, Tendermint.

1. Introduction

Modern supply chains are inherently facing complex issues such as increased cost, enhanced speed, quality, and service to meet consumer demands, resulting in high risk in supplying food products. The existing traceability systems follow a centralized architecture maintained by an authoritative third party [1]. Thus being suspectable to high risk of data modification and leakage of sensitive information. A Blockchain is defined as a digital, decentralized mechanism that saves records in distributed nodes, helps in increasing transparency, and ensures immutability and trust in transferring products among different food stakeholders [2]. The prominent benefit of blockchain in terms of transactions is that once a transaction record is created successfully, it can neither be altered nor compromised [3]. The blockchain is a mixture of multidisciplinary concepts such as software engineering, cryptography, distributed computing, and maintaining an infrastructure focusing on digital assets [4]. The main aim of using blockchain in the food industry is to solve traceability issues, including food pickup, shipping industry, and delivery operations, especially in pandemic situations. In the food supply chain context, the need for a traceability system is more during these pandemic times to act under emergencies, ensure good hygiene, maintain immutability, and provenance in the supply chain [5], [6]. Traceability helps in determining the source of the actual product, thus ensuring that it is preserved properly by maintaining quality and thus leading to the product's sustainability standards [7]. Traceability and overall transparency have become crucial and the absence of which has led to several scandals arising in global food supply chain systems (e.g., the horsemeat scandal in Europe and the melamine scandal in China) [8].

In the current ecosystem, both the supplier and buyer are unable to access the seller’s data directly, in fact, they are only analysing the outcomes required [9]. The Agricultural Product Quality Safety and Food Safety Law dictate that companies are compelled to document the whole food supply chain, comprising procurement, production, processing, packaging, and distribution [10].In the present scenario, data collection is carried out purely based on the customer’s requirements, in which retailers play an important role acting as a middleman or as an intermediary [11]. The Ethereum blockchain, in conjunction with the Ethermint smart chain, plays an important role in improving overall transaction transparency. The proposed methodology provides concurrent monitoring of the surroundings by identifying the origin of food products and exclusively finding the individual features of each farm product. In those countries with low-power internet connectivity, lags in transport and logistics services, and supply chain governance, inevitably result in higher consumer charges [12]. Smart contracts in Ethermint smart chain methodology play a core role in the supply chain industry which can address the above-stated problem. To conduct digital transactions in the supply chain, all stakeholders must agree on a consensus mechanism to proceed with document exchange, which can be applied to widespread domains [13]. Ethereum with a smart chain eliminates the middlemen and can solve many conflicts and disputes among community members of small farmers in a fairer manner [14]. Smart agreements produce high-quality byte codes in languages like C, C++, JAVA, and Python for blockchain operations [15].

The proposed system combines Ethermint with a smart chain along with the Blockchain-IoT technique by preserving the privacy of customers, especially during shipping, by ensuring data storage and distribution in the supply chain. This system can automatically verify if a product has been delivered or not. First, it loads the contents into the blockchain with time-stamped key information, which helps in avoiding duplication and ensuring that the products were distributed upon agreed conditions. Then, it returns the exact payment to the appropriate parties. The rest of the paper is organized as follows: Section 2 briefly reviews the transformation of traditional technologies into more intelligent ones. Section 3 presents the proposed Ethermint Smart Chain Storage model. Section 4 explains the smart chain distribution pattern with Ethermint logic in the supply chain industry. Section 5 provides a detailed discussion on the Performance Act of the Ethermint Smart Chain System. Section 6 reports the experimental results. Section 7 summarizes the work and outlines the future scope of the studies.

2. Transformation of traditional technology into a more intelligent one

The traditional food supply chain traceability faces many problems, such as data invisibility, tampering, leakage of sensitive information related to production, processing, collection, capturing, consumption, transportation, and retail. So the main responsibility of stakeholders lies in packing the related product details into the blockchain [16]. In this study, the authors identify several traceability technologies like RFID, Barcode, NFC, WSN, GPS/GIS, and IoT, and a relationship is established between each technology and its blockchain-based version for ensuring smooth transactions.
The proposed study of Blockchain in the supply chain is projected to develop an annual progression rate of 87% growth from $45 million in 2018 to $3314.6 million by 2023 [17]. Agri-Digital is focusing on developing trustworthy and efficient Agri supply chains through the use of Blockchain Technology (Agri Digital, 2017) [18]. In India, around 50, 000 out of 170, 000 PPE kits failed the safety and quality tests and were destroyed completely [19]. It has been informed that Amazon was forced to remove one million fake products to defend consumers from COVID-19 [20]. The Blockchain has the potential to increase efficiency by the proposed Ethermint smart chain, help in consuming time, and decrease risk in the supply chain [21]. This study, explains how traceability from the initial source (primary stage) is treated, stored, transported, and distributed for each stakeholder in the supply chain. The most crucial factors in the supply chain are transparency and traceability [22]. Most of the traceability systems like RFID, Optical sensors, Wireless Sensor Networks (WSN), and many more are poor in connecting, discovering, and recording information regarding food safety and quality throughout the supply chain. The visibility includes material cost, how packing in progress from the physical to a digital model, and performance affects the supply chain effectiveness in a very dynamic and open manner to find out the best offer [23]. Hence the authors propose a real-time eco-friendly environment to satisfy each customer with a proper list of ordered products and services that are being demanded [24] in a privacy-preserving way.

2.1 Key-Value of RFID - Blockchain in securing supply chains

Radiofrequency identification (RFID) is a remarkable wireless sensor technology that can be applied in various applications, including healthcare, the agriculture sector, asset management, and supply-chain logistics. Currently, RFID works with the server, receives a message from the reader, compares the received data with the stored data, and checks whether it is valid or not. If found valid, the server stores the data, and the tags are authenticated. The server generates random numbers and sends them as tags through the reader [25]. These tags help to track products during distribution, instead of being confined to the production stage [26]. Detecting counterfeit drugs using RFID tags is too expensive and fails to guarantee proper results [29].

In real-time testing, RFID aids in the collection of data, which is organized inside a container and divided into batches for each food product information profile. The profile grasps the product details from the basic to the end product. The RFID system connects different technologies and standards to track the traceability data in the practice of events. RFID tags with Wireless Sensor Network (WSN) help in scrutinizing the environment [27]. Walmart conducted a blockchain test to track items in the United States and pork meat in China in 2017. This blockchain test contains the records of all activities in the form of transactions, recreates product history, and recognizes product origin [28].
Traditional systems in contrast to RFID systems, suffer from more unassured authentication schemes and could be vulnerable to more impersonation attacks against tags [25]. Real-time quality monitoring offers the exclusive identity of the product to capture real data. It has the potential to overcome the shortcomings of traditional technologies and become a powerful tool for product and brand protection [30]. Each RFID address is unique to a physical address and is not shared publicly. Most of the current RFID authentication protocols require a back-end server to preserve the secret information of each product or a dedicated server to perform major functions like reading, writing and storing the data for validation [31], [32], [33], [34]. A tag concept is also used, known as an electronic tag [9]. This helps to reduce energy consumption with longer battery life and reduce the cost of energy-efficient solutions. Yet another reusable tag is attached to each tuna fish, which improves the customer experience at a low-cost [35]. RFID helps in speeding up operations, improves data accuracy, logistics management, and further improves the assurance of customers in the logistics chain [36].
RFID- blockchain combination safely holds the balanced data. While a smart contract in the blockchain is used to robotize the process, prompt events, arrange necessary terms for technical implementation and also settle arrangements for all parties. Further, RFID attached to a Blockchain product hires Ethereum to prove product ownership [37]. A smart contract plays a key role in blockchain implementation as it takes the transaction request, uses the defined policies, system calls the ordering services for the verification, and adds the verified transactions to the blockchain network [38]. Through the smart contracts, an integrity check is performed by incrementing the read count logic of the tag after every tag-reading process. Therefore its complement parts are stored in and out of the blockchain. Thus a smart contract increases information sharing, order traceability, and inventory visibility [39]. At all stages, smart contracts screen the price level and the flow of products from one move to another [40]. Currently in Blockchain, once the product reaches safely, a notification message is thrown with 'Event Stock Levels' and the product details are posted in the ledger [39]. RFID tagging helps fishermen to register with blockchain [41] and collect fish processing details and also upload the details to the distributed ledger. When the processing action is complete the RFID tag can be recovered with a QR code tag. Blockchain with Ethermint logic protects against cloning attacks in RFID-based approaches [42].

2.2 Optical use of Barcode and sensors with Blockchain in supply chains

Barcode is also known as the Automatic Data Capture technique. A Quick Response (QR) code is used for product tracking and also to monitor the complete journey until it reaches the hands of the customer [35]. French retailer Carrefour [17] started a food traceability system by encapsulating all the appropriate information so that customers can discover it by scrutinizing QR codes. It also helps in accessing and allowing them to scan the particular product and prove its reliability since it is essential for food safety and quality control [34],

[43]. Only a few products need barcodes; starting small with single GTINs avoids the most economical option [44].
DNA barcoding greatly enriches transparency and avoids food contamination within the food supply chain. This mainly helps to confirm the uniqueness of raw materials [45]. From the scientific point of view, the DNA-based technique relies on Meta barcoding and Mini barcoding. Utilizing innovative technologies, Meta helps to identify various species within complex patterns using innovative technologies, whereas Mini makes it convenient for scrutinizing refined samples with degraded DNA [46]. Researchers using DNA barcoding have thrown light on the sale of seafood products made of sharks in the UK, making customers purchase seafood products that contain endangered species [47]. Another code termed Data Matrix (DM code) is frequently used for the straight marking of parts for assembling. DM uses inkjet printing technology in agricultural research [48].
Barcode faces certain drawbacks on potential damage due to reserving large volumes of data and bulk items. These suspend on manual input, which is more time-consuming and prone to errors leading to miss-recording. The Barcode technique has to lean on the international platform repository Barcode of Life Database (BOLD). This technique is too expensive in a regular manner, and a trusted tool for continuous verification of suspicious fraud is required [49]. This method explains that each user holding a unique barcode printed on paper faces many issues in terms of cost and time [50]. Barcodes help consumers to access information stored in the blockchain with QR codes. It is stored via the mobile application.

2.3.Product tagging and recognition with Near Field Communication in blockchain

Near Field Communication (NFC) is a subset of RFID.NFC technology is innovative and fully functional, with centralized storage structures that benefit from enhanced counterfeiting attacks [51]. There are four major categories of data to be processed along the supply chain, namely (1) nodal transaction history; (2) supply chain data; (3) dedicated controllers on their predefined schema; and (4) unsuccessful validation records [51].
NFC can be combined with blockchain, helps in gathering information about the product, and enables the design of signatures for upgrading transactions in blockchain [52]. When a user wants to include their data into the blockchain, at first transactions need to be verified with the user's secret key stored on the NFC tag.

2.4. Monitoring use of Wireless Sensor Network with Blockchain in supply chains

Wireless Sensor Technology (WSN) is considered to be a core scientific path in promoting supply-chain transparency across all actors. A WSN is a distinct communication device with precision sensors. These sensors actively collect farm stage records and environmental data, thus agreeing on quick attainment and observation [53], [56]. Most popular data analytics and wireless sensor applications focus on transportation, data storage, and circulation of food items commonly known as the "cold chain" [54], [55]. In a cold chain, time-temperature measures with sensor devices linked to a WSN can assist in the realm of the quality and safety of a food product and litter the risk of decay [60]. Wireless sensors with RFID can be used to supply information directly [57].
In WSN, most of the nodes continue to be disabled for a prolonged period and also are in operations during universal calamities, and undergo other attacks such as denial of service,

node compromise attacks, and resource consumption attacks [58], [59]. WSN gathers data from different sensors and arranges different network topologies for securing long communication among nodes [46]. Wireless Sensor technology assures lower installation costs [61]. Sensor methodology carriers dispersed data acquisition to end users from anywhere, at any time, with no prior infrastructure [62]. Fixing biosensors in packed food products helps in identifying contaminated food products [57]. WSN is not apt for recognition purposes and requires an energy-saving technique for continuous detection and monitoring [46]. Further WSN have limited battery life and a built-in storage mechanism, making them unfit for continuous data transmission [64].

"The blockchain can mainly solve security and trust problems" [93]. Integration of blockchain in WSN greatly improves security and confidentiality through a dynamic key management scheme [65]. One of the greatest highlights of WSN-Blockchain applications is decentralization [64].

2.5 Tracking of supply chains integrated with GPS and GIS in blockchain

One of the most modern hi-tech systems includes the Global Positioning System (GPS) and Geographic Information System (GIS). This technology is a unified application devoted to simplex or duplex connection to accomplish optimality through each stage of the whole cycle [66]. This GPS is a satellite map-reading system that benefits users with outdoor positioning, navigating, and timing services. This positioning system helps in tracing locations that measure signals from satellites that are framed into orbital models for each satellite [68]. In a short period of time, this system provides an optimal distribution track for monitoring vehicle positioning, ensuring safety, and ensuring food quality. The paper [14] offers a GPS mode authorized traceability system known as the GPS Lab to carry out tracing and tracking to verify transparency in global supply chains intending to reduce the delivery time and qualify the freshness of each product.

GPS works continuously the entire day and is involved in a huge range of smart devices, including Android phones and vehicles [68]. This information system is susceptible to fixed point-based and brute-force attacks [70]. The most outstanding use of GPS in precision agriculture is around agricultural drones, which are used for smart farming to boost different farming practices [71]. One of the categories of GPS is Assisted GPS, which is more efficient with high-accuracy positioning and helps in identifying spatial positions by treating network resources as mobile networks [69]. Another type of GPS includes the differential GPS (D-GPS) to correct the position directed by the satellite system. RFID in conjunction with GPS provides real-time guidance for agricultural products, particularly during the delivery stage [72].

The greatest limitation of GPS is its low precision level, which renders it an inadequate sole technology in tracing applications. This poses a serious risk to user privacy [73]. Earlier results show the tracing of mangoes from the catchment region to consumers took nearly 6.5 days whereas the present blockchain study following a continuous path solves the particular issue in a few seconds [4].

2.6. Integration of IoT with Blockchain in Supply chain Management

IoT is a group of technologies with trending advancements in figures and analytics. The integration of such technologies makes them complex from a huge application point of view [74]. The bottleneck happens while authenticating, approving, and connecting nodes to the network [58]. The IoT devices constantly stream data, which leads to a high stability rate [75]. The IoT devices connect with intelligent devices using a protected software company switching from one area to another [58], [76]. Privacy and security issues in data distribution are solved using access control and authentication mechanisms [77]. The major issue faced by the IoT is its centralized structure. A lack of trust between participating actors marks an entire network failure [78]. The percentage of attacks on IoT systems from 2018–2019 crossed over 200% [79].

The IoT has a promising future in improving existing systems and tools [80]. Blockchain is a solution to address the security and privacy problems in IoT systems [74]. Blockchain, along with IoT sensors, intelligently improves supply-chain quality management [81]. The integration of IoT and blockchain with smart contracts accelerates the acceptance of Ethereum blockchain traceability [82]. The Global Data Plane (GDP) in the IoT context, combined with blockchain [83], aids in the tracing operation from farm to fresh. To achieve this goal, developed an IoT gateway with a blockchain and an occasion-based messaging technique on a private Ethereum network [84]. Each stakeholder must have complete trust in the supply chain to store their sensitive and valuable information [85]. In the Blockchain-IoT framework, the IoT can be used mainly for data assembling and transforming while connecting the physical and digital world with applications and sensors [86]. Blockchain paves way for data transparency and complexity by reducing the monetary charge for all contributors to the supply chain [87]. Further security issues of the IoT centralized method are also solved by using a lightweight chain known as Fusion to hold IoT devices [88]. IoT-Smart contracts commence potential for application in supply chain management traceability [90]. Further IoT-Smart contracts will improve the efficiency and speed of conquering information and helps in governing data productively. Certain limits have higher transaction charges and lower throughput. It is also imperative to address the issue of high gas costs in the formation, and update the product details and specifications [89].

Integration of blockchain smart contracts helps mainly in tracking spoiled food products. The joint venture helps in faster decision-making in real-time data-driven supply chain services [91], [92]. Smart contracts monitor price levels at each stage and execute event information properly [90]. It also monitors resource consumption in smart communities [45] and realizes a data-driven agriculture pattern followed in the supply chain [91]. The union of blockchain-IoT helps to increase efficiency and concurrency while lowering computational costs [93]. Further, it saves computing and communication time, automate and eliminates food fraud by validating the transactions [77]. The identities of devices attached from farm to fork are verified [78].

IOTA and IoTeX are two models of IoT platforms built on distributed ledgers [94]. Sensors are known as Taps, to help securely exchange values and execute all actions automatically [96]. IoT security elements include privacy and protection of private data and require high-end encryption mechanisms on the upper-end of the blockchain [49]. Thus Agri-BlockIoT integration in food supply chain management facilitates full traceability of saved records [95].

Table 1. Summary of blockchain-based IoT access methods for Traceability in Supply chain.

ICT used	Strength	Weakness	BC-Strength
Barcode	Enhance transparency Cut down food adulteration methods [45]. Economically feasible [45].	Barcodes are too expensive. Required trusted verification tool. Mainly for single agri-food products [57]. Relies on an international platform repository [46].	Simple to use. Read a line of sight [46]. Damaged or semi-rubbed is un-readable [46].
NFC	Capture product provenance [81]. Detect cloning and target application attacks.	High Data integrity Corruption [43]. Easily undergo active attacks.	Hold a product provenance comprising many changes holistically [52]. Track, discover modify, cloning& application-level attacks infected on products [97].
GPS/ GIS	GRASP simulated tool prevents food-borne outbreaks [98]. Optimal scattering shortens distribution time [57]. Increase in-transit visibility [99].	Simple to use and easily undergo attacks [46]. The chance of physical damage is much more [99].	Assure live cargo tracking capability.
WSN	Small communication device. Constant storage location. Rapid acquisition & monitoring. Real-time collection.	High Cost [100]. More Space. Limited Monitoring points. Not suitable for identification purposes [46].	An effective approach for secure communication and cracks energy-saving issues for constant sensing [78]. Better provision of critical resources due to high data granularity [99].
IoT	Low energy consumption[94] Improve agility & visibility. Theoretical basis to quality and improve supply chain management [81]. Dynamic policy management [101].	Data manipulation happens at all stages [40]. Generates big data and power for the supply chain [77]. Vulnerable to security issues. Require aiding technologies for data platforms and accountability. Hardware Dependent [77]. Computing power & environmental cost. Increase market value drastically [40].	Decrease opportunistic behavior [102]. Reduce storage overhead [45]. Increase revenue [45]. Resolve identity management [94]. The overhead charge will be minimized [45]. Speed up transactions [77]. Hyper graphs reduce the need for storage [45].

3. The Proposed Blockchain Model

We propose an IoT-Blockchain-enabled smart chain for better performance across the system. When a farmer receives a request from a buyer, it adjures the smart contract to verify if it's a valid request. A request is included in the contract in the form of smart tokens. These tokens are framed using access control policies, which are in the encrypted form and these tokens then give selected access to secret keys and authorize specific individuals to decrypt the content. The owner can then fetch the actual copy of the corresponding token, where one can record and retrieve data leaving no room for tampering. Every transaction is validated by forming a consensus with all participants, and if the data content is valid, it is added to the chain. By, this method, the other options in a supply chain with the support of data can also be implemented to achieve customer benefits [39]. More over blockchain helps to reduce the time gap in terms of tracking from weeks to seconds, approx. 3.2s, helping to easily identify contaminated food products and increase revenue, which in turn increases trust among stakeholders [103].

The overall system architecture is shown in **Fig. 1**. The entire system is under IoT surveillance where Trusted Requirement Enhanced Execution Contract (TREE-CT) followed by a smart chain provides complete security to the entire system. The TREE-CT protects confidentiality and can deliver secure environments for running contract code, guaranteeing execution integrity. Stored data is secured and arranged in the following two ways. 1). IoT devices routinely transfer data to the MQTT server and blockchain, 2). The Blockchain continuously checks data via (TREE-CT**)** and updates the log events.The proposed Smart chain works in detail as follows:

(1) Producer: Information about the farm and agricultural product activities is included. From the producer, there is a digital data flow (i.e. RFID, QR codes, NFC, GPS/GIS). Every action that occurs using digital technologies, is chronicled on the blockchain, thus creating a permanent record of the entire process.

(2) Smart Contract: A smart contract will define the identity of the user and helps in preventing food fraud by validating all transactions. Data are recorded in the form of transactions on a blockchain which increases the real-time ability of decision-making by saving intercession cost, accuracy, adequacy of information, and communication time. Further, reducing the amount of expenditure for the stakeholders in meeting all policies, is also reduced and thus making them more competitive [19], [104]. The smart contract ensures that only valid transactions are executed in the network thus eliminating malicious activities [105]. The current methodology [101] ensures high security using cryptographic calculations that will not allow unapproved parties to enter the blockchain network. Our system adopts two smart contracts known as the Requirement contract for data storage and the second contract known as the Enhanced contract for distribution. A Requirement contract defines the quality standards of a specific item. Thus holds sophisticated data and stocks only the unique hash value with IPFS in the blockchain. The remaining contents will be stored in Mongo DB. Enhanced Contract feeds data from an external party. Both these contracts are stored and available as public on the Ethereum blockchain.

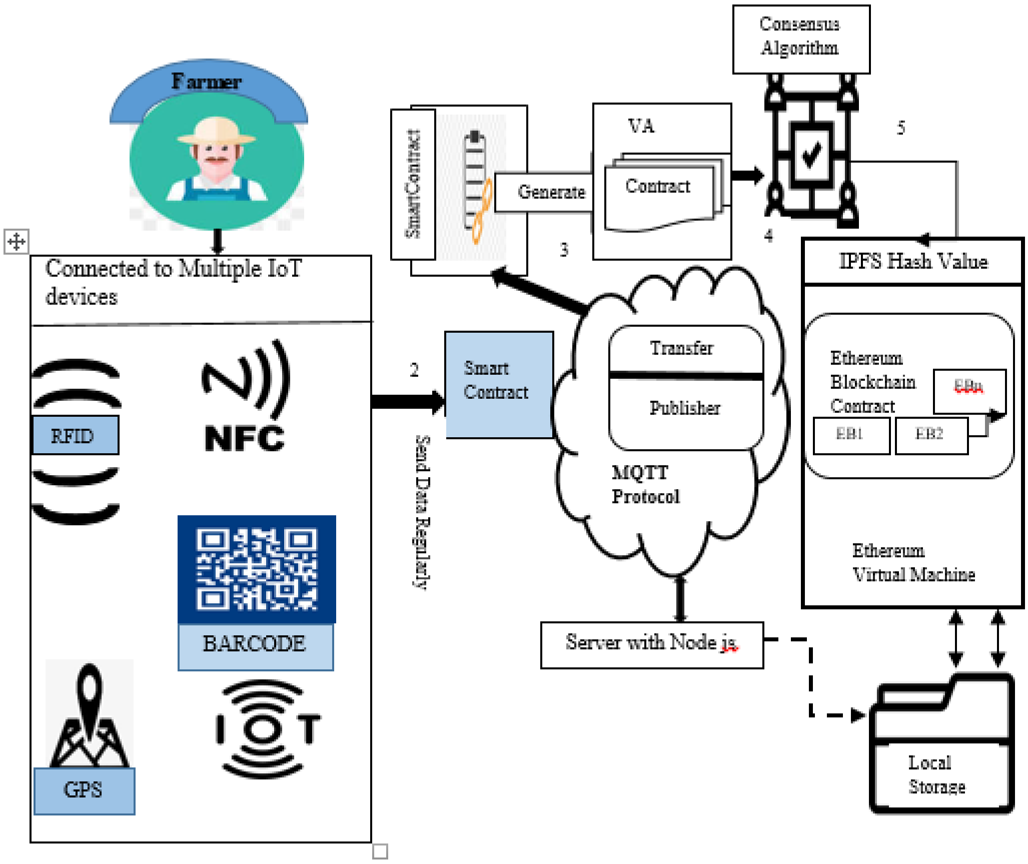

Fig. 1. Overall System Storage Overview

(3) Technology-enabled systems reduce risk in the food supply chain by ensuring the authenticity of food products, reducing food-crisis crime and quality concerns, and by safeguarding stakeholder data through a balance of production and consumption. Technology supports food producers, retailers, authorities, and even end-users to take prompt decisions by providing them with the right data that boost decision-making process ability [107].
(4) Processing: The entire information includes the stages of the product, how it's processed through a smart contract, undergoes certain methodological processes, and different participation logic. The primary reception contract includes hygiene, secondary handling, distribution, retail, and domestic needs [98].
(5) Message Queue Telemetry Transport Protocol (MQTT): Data is collected directly from the farmer to prove the validity of the farm products, depending on the Trusted Requirement Enhanced Execution Contract (TREE-CT). MQTT acts as a connecting agent between IoT devices and blockchain. This is suitable with low bandwidth and high reliability. Both IoT and blockchain [94] are connected via the MQTT protocol through HTTP requests for a specified time [106]. A system that uses the MQTT protocol requires many users to interconnect with a server called the MQTT broker. It holds two main elements known as publish and transfer. MQTT plays a core role in collecting messages from the publisher and transfer those to specific addresses. Each user will receive updated posts on any topic and publish those messages.
(6) Verifying Authority (VA): The contract set is a fixed structure including a start state defined with a set of attributes and methods. The contract set stores the attribute values in the

blockchain and thus may be changed when a method is called or executed. VA generates the contract set and checks if it satisfies the contractual policies. If satisfied, generate a contract and then forward it to the tendermint mechanism, which helps in authenticating the process faster and later store it in the smart chain as a contractual document [108].
(7) Consensus Mechanism: The consensus mechanism is considered the Ethermint core operator. Each block is added for verification and once approved, correctly store in the blockchain network without depending on any intermediaries [51], [109]. Consensus relates to the set of rules and mechanisms that verify the integrity, authenticity, and accuracy of data [111]. It also certifies whether a new block has been added to the chain properly or not [26]. The main attraction of using consensus is that actors in the supply chain cannot change the rules since a contract is legally bound between two trading partners [110].
(8)IPFS Storage: The storage size issue of blockchain can be solved by uploading smart contract code into a local disk known as Interplanetary file systems (IPFS)[106], [88].IPFS system has been framed to address the issue of file redundancy [75].In IPFS, a verified block is distributed and only the IPFS hash value is stored. In IPFS, one can load high-capacity files efficiently by a unique hash value. The best quality of IPFS is termed as a permanent web, entailing data published to a network that will remain intact and available forever [40].IPFS stores sampled data based on a double-blockchain and can directly access the ledger data for agricultural purposes. This explains the fast retrieval of data into IoT networks, which greatly saves time in interactive network communications. [112].
(9)Local Storage: Mongo DB is a distributed database built in modern applications having support from Cloud. It stores data in the form of JSON format [106]. It supports aggregations, and arrays, with a comprehensive set of tools that make the actions remarkably easy for everyone. The purpose of this storage medium is to collect major content like a complete description of the whole product. It stores food events due to its high speed and makes it easy to query the expressions embedded in documents with three functions retrieval, insert, and delete [111].

3.1. Dataflow of the Smart chain System

The data flow describes how to store data into the blockchain and classify those data based on two types of data objects; 1).address and 2).bridge link. When the producer receives a request from the customer, it invokes the smart chain contract for verifying the query and frames the decision upon accepting or denying it [113].
Step 1: An address contains a set of public keys that serve as a channel between anonymous farmers and consumers.
Step 2: Bridge Link connects with an address on the contract and found benefits for the farmers in building up the relationships. The Bridge link manages nodes that share the same database session.
A farmer can create a smart contract upon verification of input data address in the following way:

1. Create a public/private key pair.
2. Include primary heads in the form of a ticket-granting ticket for the relative user IDs. This address helps in transferring private information securely to IPFS.
3. Generate a hidden service identifier, which helps to uniquely identify the address and sign it with the private key.
4. Issue the signed data as the address on the smart chain data rack. This chain connects with the addresses. The Bridge link data service holds the following fields:

Only once per user login session.

$$P \rightarrow SCs \quad Dp \,||\, Pp \,||\, IDc \quad (1)$$
$$SCs \rightarrow P \quad Ticket \quad (2)$$
$$P \rightarrow C \quad Dp \,||\, Ticket \quad (3)$$
$$Ticket = EkI\,[IDp \,||\, ADp \,||\, IDc] \quad (4)$$

Table 2. Symbol Description

Symbol	Definition
P	Producer
SCs	Smart chain Server
IDp	Identity of many users on P
Pp	Password of the Producer
IDc	Identity of many consumers on C
EkI	Secret Encryption key shared by a unique identifier
ADp	Network address of producer

4. Distribution pattern implanted in Supply chain using Ethermint Smart chain

Blockchain technology in the supply chain industry has many benefits in buying, selling, and transporting mechanisms. The producer sells the product into a smart chain and can trace the origin of supply for the product [113]. The smart chain pattern allows each supply chain holder to hold information regarding the whole product and update its status on the blockchain network. This pattern increases the customer trust and confidence associated with product characteristics [2]. To reach this goal, a Smart chain model is projected covering six layers as shown below in **Fig. 2**.

The first layer in the smart chain is Supply chain layer explains the system input sources, including farmers, suppliers, service producers, and customers. A device in the supply chain act as node, and each node contains a copy of the blockchain. The components of this layer are linked with the network, and the subsequent layer supports and builds a reliable and efficient supply chain [114]. The second layer is the IoT Access layer which conquers real-time information. This layer collects the inter-organizational information from the farmers, communicates with service providers, and delivers to a customer with proper planning across the supply chain using traditional technologies like RFID, QR Code, NFC, GPS, and IoT.

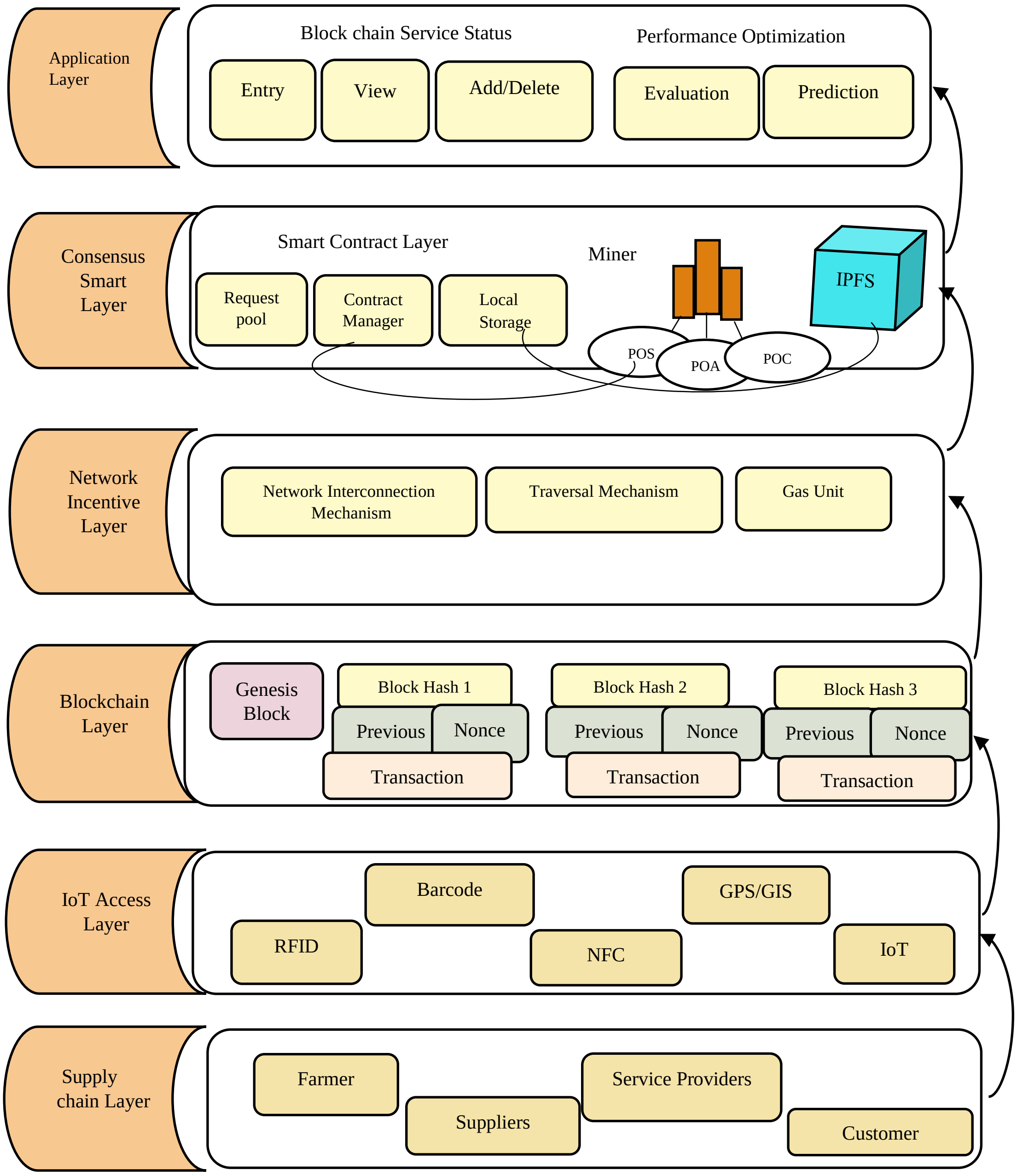

Fig. 2. Smart Chain model for Supply chain distribution evaluation

Stakeholders maintain proper coordination and cooperation, which helps in increasing efficiency and thus leads to improving the whole chain activities [115]. The verified data in the storage part is circulated and moved to the next layer. The third layer is known as the Network Incentive layer, where each transaction has undergone mining operations. For each transaction, a validator node verifies the blocks and transfers them to a consensus mechanism. On completion, valid transactions are accepted and new blocks are added to the blockchain. The blockchain uses Merkle tree functions to store each transaction separately. The fourth

layer called the Network Interconnection layer provides a framework for connecting objects with applications and improving the services. This mechanism can transform supply chain distribution into a smarter one. This layer embraces the network interconnection and traversal mechanism and includes details on Gas price. The traversal mechanism finds exact data from the blockchain store and traces the entire transactions that include the encrypted data.
In the gas unit, most miners impose the consensus fee to be paid during computation within the virtual machine. The fee decides whether the transaction will take a longer time to record or not. If higher the transaction fee is, transactions will be forwarded and recorded faster. The fifth layer, the Smart consensus layer, includes smart contracts that are self-enforcing agreements that move within the blockchain.Smart contracts protect privacy through access control and authentication mechanisms that ensure privacy and security in data distribution [116]. This executes complex functions and thus simplifies communication with other nodes in the blockchain. This layer undergoes transaction verification and new transactions are verified and transferred to the IPFS network, and only the IPFS hash is returned. This helps to reduce the size of the smart contract code stored in Ethereum.The task of the topmost layer is to evaluate performance management and blockchain service status. The main aim of the blockchain service status is to satisfy the functionalities of the system. This layer accepts all data to measure the supply-chain performance. Based on the status, data will be shared with the stakeholders in the blockchain platform. In a smart chain, the performance model and evaluation process include registration, collection, production, packing, examining, selling, and reporting products in a safe, transparent, and traceable manner. Quality-deficient products will be eliminated, by entering into other stages of the supply chain by this method.

4.1.Smart Supply chain distribution Pattern

Transportation and storage are out of the manufacturer’s direct control and often diverge from specifications [107]. These Smart chain runs from production to delivery and undergoes various stages in detail, such as paper recording, procuring the product from farmer to manufacturer, and providing the final delivery to the customer. Traditional technologies struggle to provide privacy, transparency, and anonymity to all stakeholders [81]. The advantage of a smart chain is to provide authentic end-to-end tracking, where each organization holds an immutable record of all its dealings to enhance visibility among service providers and customers. To ensure a strong and trusted relationship, supply chain stakeholders consider real-time communication, collaboration, and transparency, which have a more competitive advantage in terms of outcome [117].
Fig. 3. A explains overall blockchain-based supply chain management. At the initial stage, creates the first smart contract between producer and manufacturer and include details regarding the farm products. Further, transfer them to the manufacturer, and he will include the details like the quantity, ingredients, date of supply, and manufacturing. The second contract is signed between the manufacturer and the distributor. The details include distribution areas, units, distribution date, quantity, and address of the retailer, which are transferred into the blockchain. The third contract is signed between the distributor and the retailer. After retailers receive the end-product, update it with the manufacturer and check the expiry date, cost of the product, ingredients, and standard admissible units. Finally, customers can purchase using blockchain, ensuring the security of sensitive data [81]. Smart contracts act only as account holders. Each account may receive or send transactions that are fully controlled by its contract.

The main advantages of the proposed **Fig. 3. B** model are 1). Each smart contract has a complete formal verification framework to check whether the smart contracts are on a complete theoretical basis; 2). All smart contracts are subdivided into different sets for distributed verification following hierarchical decomposition, which greatly improves flexibility and efficiency along with security verification and provides high scalability. Third, it encourages large-scale supply chain development, low storage costs, large storage capacity, and offline processing with chain integrity are included. All the above smart contracts can implement stateful functionalities that receive arguments and describe states instantly.

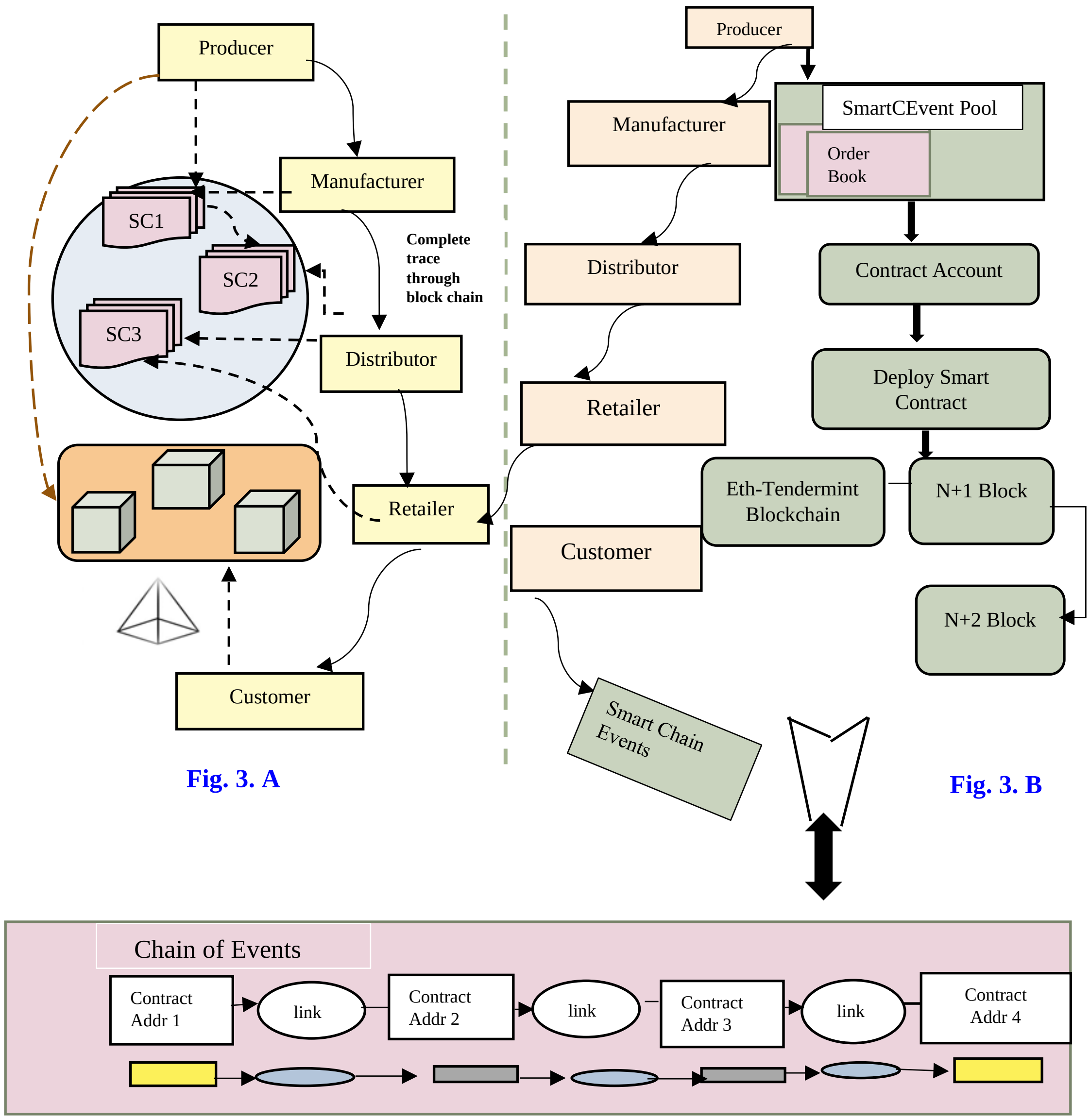

Fig. 3. A **Fig. 3. B**

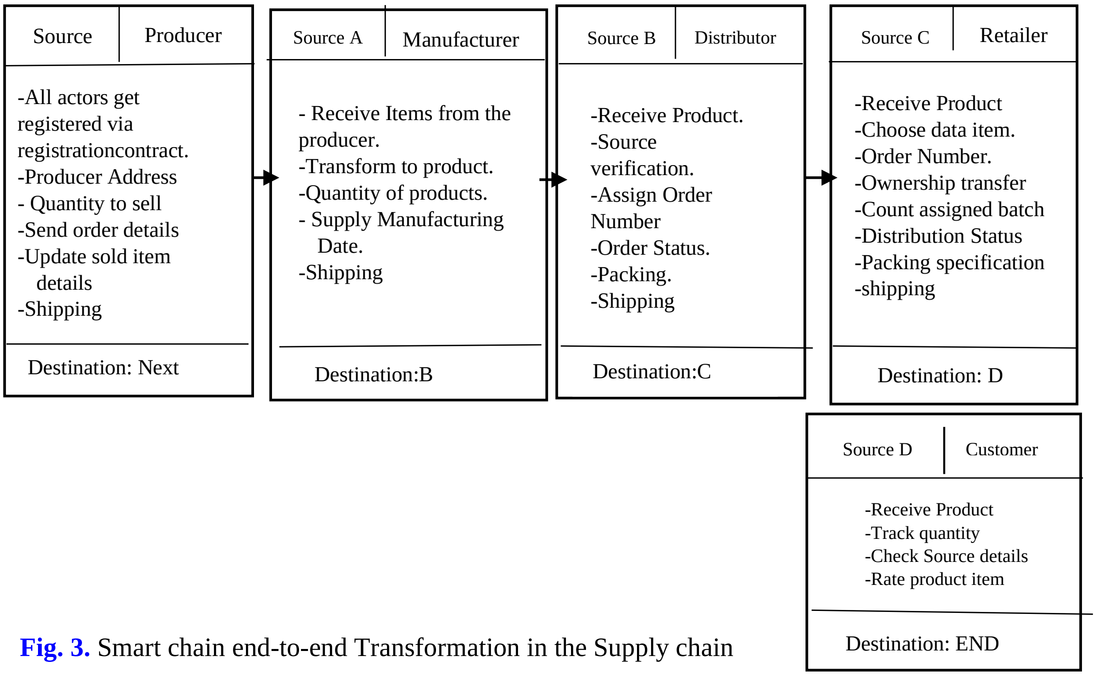

Fig. 3. Smart chain end-to-end Transformation in the Supply chain

The core entities included:

Smart Contract Pool: A Smart contract pool is a set of data structures that store awaiting transactions until they are validated. A Smart pool is included for continuous deployment of contracts during low load hours. This states that if gas usage is increased, the contract deployment transactions will be more luxurious. Once a smart contract has deployed, the contract address is reverted and deposited in the pool. The major function of the contract pool is the agreement policy. Each service provider holds agreement data with attributes, stating conditional services were implemented properly. If the report states, that the service was implemented properly, the consumer will hand over payment to the producer through the smart contract [119]. If the consumer reports the service has not been executed properly and the providers claim a disruption, the funds are returned to the customer. Order Book: This book stores upcoming orders from multiple users. The producer checks whether it's a valid order or not. If so, it places the order in a queue. Models are then evaluated based on their cost and time of creation.

Farmer to Manufacturer: Farmer, the source has to be registered in the system. Each product has a unique code that holds the product type, personal details, hash file, manufacturer address, batch number, total quantity, and balance product available after supply. The procedures of product registration, relocating, and tracking are executed through the association of smart contracts named "Contract Address." After registration, public and private keys will be generated. Upon consensus verification, the farmer confirms the delivery, and the manufacturer issues the order receipt. The smart contract will provide delivery notifications on querying the log records according to the Ethereum address, confirm the validity of the signature, and update the latest status regarding product transformation. The manufacturer summarises the product information and registers it in the system. An international coding standard, UCC-13, is used to encode the product. UCC - Prefix the Item Reference Number. The 13th digit represents a digit check. The product produced is assigned to a batch with a

specific batch number. On transferring for the first time, one needs to enter the product code and batch number, or else one can refer to the previous transaction. The paper [120] explains how storing large amounts of data in pharmaceutical environments ensures end-to-end traceability and how each of the medical products is tracked by its batch number.
Manufacturer to Distributor: The Manufacturer identifies the required products and collects the necessary data and checks whether the sufficient quantity is available to meet customer demands, It makes sure the product satisfies regulatory standards. The manufacturer holds the details like Product Name, Product ID, Quantity, Number of items, and all batch details. All are uploaded into the contract address, where product certification and material composition are included as hash documents in IPFS. During the entire process, the distributor may take special care when dealing with high-valued products.
Distributor to Retailer: When an order is forwarded by the distributor, the status of the order is checked and an order has to be placed successfully. The product has to remain uninterrupted during the traceability process. By using smart chain logic in retail, the user can detect the destination and exact location of the item.
Retailer to Customer: Retailers acquire products and sell them to the customers with whom they have a direct trading relationship. The core element of the system is batch allocation. Each product can be identified by a batch ID, so the users can trace it on a standard interface. At any stage, batches can be traced back on request of information [9]. At first, a customer frames a purchase request that includes the buyer’s and seller’s addresses, the code of the product, the batch number, and a request for the Ethereum account public key along with the signature to confirm the identity. After confirming, he will order the product, from the smart pool, and collect the product code. The smart pool responds to queries and sends product details. For customers, supply chain efficiency could be improved by reducing the duration of pending cash backlogs.
Shipment: In Lelantos's shipment logic, the system itself manages the shipment. The main aim is to protect the privacy of customers with an anonymity-preserving delivery method. A single smart contract combined with blockchain is used to redirect shipments [121]. The customer follows asymmetric encryption logic, known as “onion routing, " where it sends the delivery address in an encrypted form. The sender and the receiver can each be identified separately. But cannot be identified as communicating with each other [122]. Shipping documents include loading bills, advance shipping notes, clearance papers, etc. Lelantos purely interacts with an enhanced contract from its wallet. A customer can use Lelantos shipping mode, a customer-side application to interconnect with service providers and distribution agents. The system should be able to handle all continuously generated events on time [123]. The smart contract frame all the rules and the receiver have to credit the payment before shipping, and if the shipment meets the final destination, the payment would be forwarded to the producer. If any violations occur, the payment is cancelled and the funds are traced back to the customer. This implication helps in effective shipping modes [121], [122].

5. Analysis of Ethermint Smart chain system

One way to improve the performance is by concurrent execution of smart contracts. Privacy and confidentiality is the greatest challenge of blockchain. Most of the measures end up in failure, especially in dealing with transactional privacy [124]. This paper follows the smart chain execution framework to gain an on-chain transaction proposal with the Ethermint algorithm [93]. To show in detail how Ethermint action works, elaborate on the following points:

1. A Requirement smart contract is typically executed twice during its entire cycle.
2. First, in Ethermint, a hero node creates the main block and is verified by the miner.
3. The client will first telecast the computation contract to each node. For each lock, there is a subdivision of the processes known as validating for generating blocks.
   3.1 A subset of the processes is known as peers, where all processes can be connected indirectly through the Gossip protocol [24].
   3.2 On request, data will be processed and valid transactions are accepted.
4. The validator node verifies the blocks and hands them over to the consensus mechanism, which adds new blocks to the smart chain. To find a solution we assume f<n/3 where f is a validator and n is the number of validators participating in a single instance.
   4.1 Validators communicate with each other and ensure the blockchain current contents. It can reassign validators to overcome potential issues with the process of centralization logic.
5. On execution, hero nodes collect all newly added blocks and assign them as batches in transactions, and use a conceptive concurrency control algorithm to suit the real-time execution of smart contracts.
6. Consider certain communication primitives during a broadcast to illuminate the basic logic behind the conceptive concurrency control algorithm. We have two operations like read and write actions to perform the transaction. It will calculate the memory address based on the type and length of the data and store it in the word info-beknode. If the writing operation is being carried over, then the data will be written into a write module. After completing the entire action, it stays idle and pause for the next operation.

Table 3. Concurrency control action logic

Message Field	**SourceID**	**Destination ID**	**Message Stuff**	**Definition**
Read	U1	C1	P, A	Processor P performs a read miss at Address A, request data and load data into blockchain
Write	U1	C1	P, A	Processor P performs a write actionat Address A, request data and make P as the active owner
Fetch	ADDR:U1	Remotenode/Cache	A	Fetch the block and change the state of Address A in the remote location.
Invalid	Local node	Remote node	A	Mark all data invalid at are caching the block at Address A.
Data Replay	Home Directory	Local node	B	Returns a data value from home node
Data Write	Local node	Home directory	A, B	Write an Acknowledgement back for Address A.

Home Directorblock state can be cached.

Local Node: The node from which a request originates.
Home Node: The memory location and directory address are stored in a safe node.
Remote node: Remote node carries a copy of the blockchain and maintains protocol.

7. Conceptive Ethermint concurrency control logic follows a round-robin fashion. Each round indicates a move from one stakeholder to another until it delivers to the customer.

6. Evaluation Results

To securely transfer the food items from farmer to buyer, a Smart chain architecture is framed. The Ethermint Smart chain is proposed for data storage management and fine distribution of products from farm to dining. This is much easier than using a conventional database system. The data is collected in a web manner using high-end systems as tags for each transaction. The experimental result shows that the overall activities in various parameters are storage overhead ratio and distribution head ratio. The storage overhead ratio is 72.81%, the distribution head ratio is 74.43%, and on a theoretical basis, the overall performance ratio is 92.30%, which is better than the existing research works. By experiment, it is proved that the proposed model can process thousands of transactions per second, which ultimately increases the throughput level and reduce the system delay. In addition, our framework provides real-time traceability. A customer can download all the purchased products from the web application, which is built on top of the Application programming interface (API). The API is linked to Ambrosus's data storage infrastructure, making it reachable to anyone who needs to verify the authenticity of the product.

6.1 Data Storage Ratio Calculation

Requirement-based contracts are used for storage purposes, which further increase linearly as the number of input and output transactions increases. The communication cost completely depends on the storage size of the data of the respective account. In our proposed model, the storage space is adequately more when compared to the traditional models and Ethereum storage contract form. As shown in **Fig. 4(a)**, the total storage space occupied under different storage strategies increases continuously with the increase in the number of nodes in the blockchain. The growth rate of storage space under traditional storage methods is much faster than that of the storage strategy followed by the smart chain. When the number of nodes in the blockchain is 10, the average storage footprint used by a smart chain is 46.78% compared with the traditional algorithm and 19.49% lower than the requirement-based storage contract.

6.2. Lelantos-based data distribution

This applies to the mode of packets received successfully through Lelantos logic to the cumulative number of packets and is distributed upon request. **Fig. 4(b)** explains on distribution overhead. Compared to the traditional distribution pattern, the proposed model works better in all stages from the production area to the dining space. In the traditional method, it acquired long waiting hours (around 6.8 hours) and more space is occupied for one move (from production to manufacturing unit), whereas in the proposed total space occupied is very less, i.e. terms of Megabytes. This proposed method used only 2.8 milliseconds to move from production to manufacturing space.

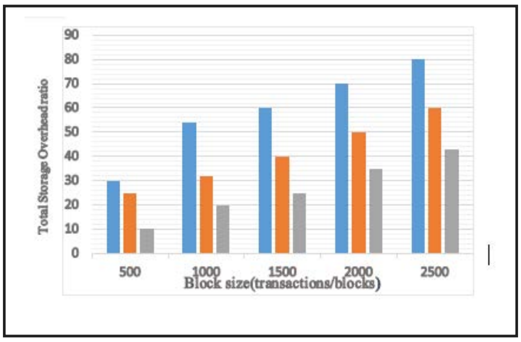

Fig. 4(a). Total storage overhead

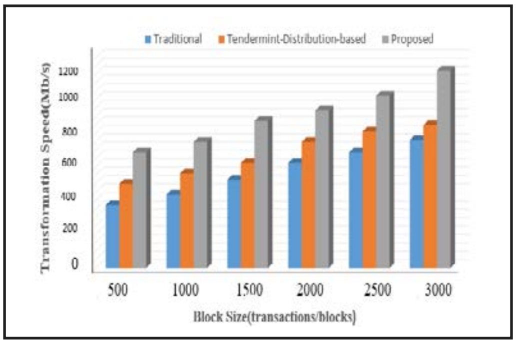

Fig. 4(b). Distribution ove

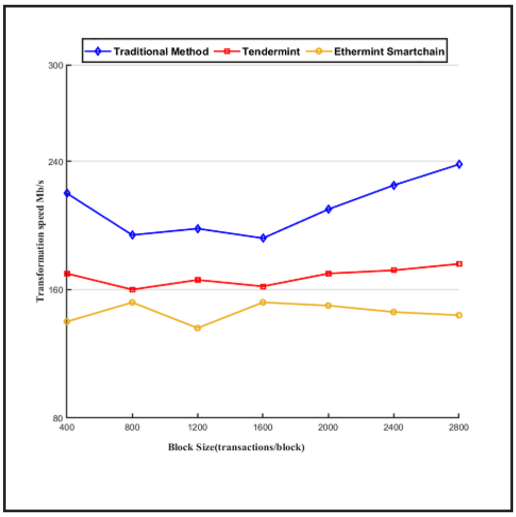

Fig. 5(a). Transformation Speed

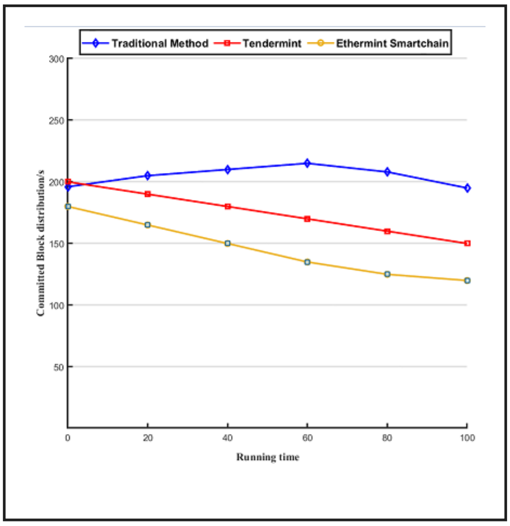

Fig. 5(b). Distribution times

As shown in **Fig. 5(a)**, the transformation speed under different storage strategies using Ethermint smart chain fluctuates slightly, but remains stable as the number of nodes in the blockchain increases. In **Fig. 5(b)**, with the increase in block size, the transformation speed under different storage strategies using the Ethermint smart chain has shown a skyward trend. When the size of the block in the blockchain is 1200 transactions, the proposed method improves the speed by an average of 7.92% compared with Tendermint mode and an average increase of 29.61% compared with the traditional method.

Remarks

Based on our proposed work, storage and distribution have successfully carried over using Ethermint Smart chain followed by Trusted Requirement Enhanced Execution Contract

(TREE-CT) architecture pattern. However, it is anticipated that storage space complexity can be further improved.

7. Conclusion

This article introduces the difficulties and challenges faced by current IoT devices in food supply chain traceability systems. Thorough analysis from the customer, we framed a smart chain system with Ethermint logic on the blockchain network. To protect sensitive information, Lelantos mode is used for shipping, which ensures the personal security of information, and is free from many active attacks. The proposed system can rebuild the customer's confidence in the food chain industry. A key finding from this manuscript is that the producer and customer need to share accurate information across trading partners to meet the operational requirements. Direct information exchange happens through smart contracts following the Ethermint smart chain without giving up anonymity within and across the supply chain. We recommend the Ethermint Smart Chain as a new way of connecting, storing, and exchanging information in a privacy-preserving mode. The main contribution of this study is to determine, illustrate, compare, and analyse the multifaceted techniques for supply chain storage and distribution. It is a complex process affected by many factors, such as environmental factors, applied areas, data collection, and so on. In recent years, the food collection from urban and rural areas is very difficult and keeps on increasing constantly. This has led to congestion and delays in bringing the product to market.

In the future, a system with complete trust in the food items during transportation from farm to dining must be developed considering the discrete parameters such as minimum time, minimum space, and maximum speed. Such a system could yield promising results. Similarly, it reduces human interference with the system and provides efficient flexibility and accuracy. There was no recent review based on an algorithmic approach to compare and investigate how the new techniques predict certain parameters in transportation efficiently. Constructing such a system allows the customers to likely purchase products with an improved sustainability footprint. The government should make it mandatory, to implement an open pricing system, which will help farmers to deliver fair prices for their product, and further helps to raise their standard of living. Moreover, we have proposed some promising research directions based on the analysis that can be implemented in the future to provide effective optimized solutions.

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