

Enhancing Health Product Traceability on the Blockchain: A Novel Approach for Supply Chain Management inspection to AI

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Abstract

INTRODUCTION: Blockchain technology is being investigated as a viable solution due to the industry's growing requirement for accountability and traceability. This study describes a fresh method for tracking down medical products that makes use of a decentralised smart contract network set up on the Ethereum blockchain. In order to enable secure and auditable tracking of health products throughout their lifecycle, the suggested system, named "HealthProductTraceability," makes use of the transparency and immutability of blockchain.

OBJECTIVES: The system uses a "Product" struct to hold pertinent data such as the product name, batch number, temperature, producer, and distributors. To quickly get product information depending on the batch number, a mapping is used. The use of tools to manufacture items, send them to distributors, and market them is one significant contribution of this research. By demanding validation tests, such as verifying that batch numbers are unique and exist before carrying out certain activities, these functions protect the integrity of the traceability system.

METHODS: In order to enable interested parties to track the product's travel and temperature changes, the system additionally emits events for product manufacture, distribution, and temperature adjustments. The suggested system is innovative because it can track the temperature of health items from beginning to end on a decentralised, open platform.

RESULTS: By utilising blockchain technology, the system lessens reliance on centralised authorities, fosters stakeholder trust, and minimises the likelihood of fraud, forgery, and tampering in the supply chain for health products. The contract's architecture recognises some of the issues with blockchain technology, including scalability and privacy. By investigating solutions like sidechains, off-chain transactions, and enhancements to consensus methods, scalability issues are solved.

CONCLUSION: In summary, the suggested HealthProductTraceability system offers a creative and practical solution to the traceability issues facing the health product sector. The solution provides improved transparency, security, and accountability by utilising blockchain technology, paving the path for a more dependable and trustworthy health product supply chain. To increase the system's usefulness and adoption in real-world circumstances, further research can investigate scalability and privacy issues.

Keywords: AI, Block Chain, Smart Contracts, Traceability

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1. Introduction

In particular in sectors where quality control and traceability are of utmost importance, supply chain management is essential in assuring the safety and integrity of health

products. It is difficult to address problems like fake goods, temperature control, and provenance verification when using traditional techniques of tracking and confirming product information because they frequently suffer from inefficiencies and a lack of transparency. Blockchain technology has shown promise in addressing these issues by

offering a transparent, unchangeable, and decentralised platform for data management.[1].

This study examines how a cutting-edge method built on blockchain technology can improve the traceability of health products. We seek to address the drawbacks of current supply chain management systems and enhance the transparency and effectiveness of health product tracking by utilising the special characteristics of blockchain, such as decentralisation, immutability, and cryptographic security.[2].

The main goal of this research is to develop and put into use the "HealthProductTraceability" smart contract-based system, which will allow stakeholders, such as producers, distributors, and regulatory agencies, to safely and effectively track the movement of medical products throughout the supply chain. The suggested system will make it possible to track crucial variables in real-time, including temperature, batch numbers, and distribution patterns, giving users a complete picture of the product's lifecycle.[3].

Our method offers various possible advantages by utilising blockchain technology. In the first place, it improves the authenticity and provenance verification of health products, lowering the possibility of fake or subpar products entering the market. Second, it makes real-time temperature monitoring possible, ensuring that goods are kept and moved within a range of acceptable temperatures, preserving their quality and efficiency. Third, the transparency of blockchain encourages cooperation and responsibility in the supply chain ecosystem by increasing trust among stakeholders.[4].

We will run simulations and experiments utilising a test network to assess the viability and efficacy of our strategy. In order to determine the suggested system's practical usefulness in real-world circumstances, we will also analyse the system's performance and scalability. Additionally, we will consider the potential drawbacks and restrictions of putting in place blockchain-based traceability systems and suggest mitigating measures.[5].

This study intends to add to the body of information already known about supply chain management by presenting a fresh method for leveraging blockchain technology to improve the traceability of health products. The findings of this study could completely alter how medical products are tracked, guaranteeing consumer protection, regulatory compliance, and increased supply chain effectiveness [6].

2. Related Work

This study intends to add to the body of information already known about supply chain management by presenting a fresh method for leveraging blockchain technology to improve the traceability of health products. The findings of this study could completely alter how medical products are tracked, guaranteeing consumer protection, regulatory compliance, and increased supply chain effectiveness [[7].

The potential of blockchain technology to enhance health product traceability has been recognised in several research. Blockchain provides a transparent and impenetrable platform for recording and validating product-related information along the whole supply chain because it is a decentralised,

immutable ledger. Automation of numerous operations, including product development, delivery, and temperature monitoring, is made possible through the use of smart contracts. With the help of these capabilities, health items can be tracked and monitored in real-time, preserving their integrity and quality.[8].

Enhancing stakeholder trust is one of the main benefits of using blockchain technology for health product traceability. By utilising the decentralised nature of blockchain, all supply chain players can access a shared and synchronised database, doing away with the need for middlemen and lowering the possibility of fraud or data manipulation. The collaboration and accountability among producers, distributors, regulators, and customers are encouraged by this open and distrustless environment.[9].

Innovative methods for establishing health product traceability on the blockchain have been proposed in a number of research articles. To ensure correct handling and storage of medical supplies, some research has concentrated on the integration of Internet of Things (IoT) sensors to collect real-time data on factors like temperature, humidity, and location. These IoT-enabled blockchain solutions give an extra layer of protection and allow for automatic triggers or alarms in the event that storage conditions are not appropriate.[10].

Additionally, for the purpose of tracing medical products, experts have looked into how to combine blockchain with cutting-edge technology like artificial intelligence (AI) and machine learning (ML). Large amounts of data gathered from blockchain and IoT devices can be analysed by AI and ML algorithms to find trends, spot abnormalities, and forecast possible hazards or supply chain disruptions. These intelligent solutions can improve decision-making procedures and enable proactive actions to stop the sale of fake goods or quickly address quality issues.[11].

When putting into practise blockchain-based traceability solutions for health products, interoperability and standardisation are critical factors to take into account. Standardised data formats, protocols, and ontologies are essential for ensuring seamless integration and information flow between various stakeholders and current systems, according to numerous studies. Additionally, using industry-wide standards and interoperability frameworks can make it easier to comply with regulations and provide global traceability across numerous jurisdictions.[12].

Despite the potential advantages, there are difficulties and restrictions in putting blockchain-based traceability systems for medical items into practise. Significant barriers have been identified as scalability and performance difficulties, such as transaction speed and network congestion. Off-chain transactions, sidechains, and upgrades to the consensus algorithm are just a few of the options that researchers have suggested to address these issues and improve the scalability of blockchain networks.[13].

The blockchain's ability to track health products faces problems related to privacy and data protection. Despite the openness that blockchain offers, it might not be desired or even allowed by law to make sensitive information accessible to all users. The use of privacy-enhancing methods, such as

homomorphic encryption and zero-knowledge proofs, can be used to safeguard sensitive data while ensuring transparency and auditability [14].

In conclusion, blockchain technology has enormous potential to improve supply chain management and health product traceability in the healthcare sector. The studies analysed in this literature review show that blockchain-based solutions are practical and advantageous for ensuring the reliability, security, and authenticity of healthcare items. A revolutionary approach to health product traceability can be achieved by utilising blockchain's decentralised and transparent nature, integrating IoT and AI technologies, and tackling scalability and privacy problems. This will create trust, collaboration, and accountability throughout the supply chain. Realising blockchain's full potential in reshaping the traceability of health products will require more study and development in this area [15].

2.1. Proposed Model

The algorithm of the proposed model is written below.

ALGORITHM:

1. Declare struct "Product" with relevant properties.
2. Create mapping "products" to store products by batch numbers.
3. Declare public variable "productCount" to track total products.
4. Define events: "ProductCreated", "ProductDistributed", and "TemperatureUpdated".
5. Implement "createProduct" function:
 - Check if batch number already exists in "products" mapping; if yes, revert.
 - Create new Product object with provided values and empty distributors array.
 - Add new product to "products" mapping.
 - Increment productCount.
 - Emit "ProductCreated" event with relevant details.
6. Implement "distributeProduct" function:
 - Check if batch number exists in "products" mapping; if not, revert.
 - Append distributor's address to distributors array of corresponding product.
 - Emit "ProductDistributed" event with batch number and distributor's address.
7. Implement "updateTemperature" function:
 - Check if batch number exists in "products" mapping; if not, revert.
 - Update temperature of corresponding product in "products" mapping.
 - Emit "TemperatureUpdated" event with batch number and new temperature.

Explanation

We start by creating a "Product" struct, which will house the pertinent information about a health product. Properties like name, batch Number, temperature, manufacturer, and distributors are included in the struct. We then create a mapping called "products" to act as a repository for the products. The batch number serves as the key and the Product struct serves as the value in the mapping. This makes it possible to quickly retrieve product data depending on the batch number.

We declare a public variable called "productCount" to record the total number of products manufactured. To offer visibility and traceability within the contract, three events are defined. When a new product is made, the "ProductCreated" event is released, which includes the batch number, name, temperature, and manufacturer's address. When a product is distributed to a distributor, the "ProductDistributed" event is triggered, providing the distributor's address and the batch number. Last but not least, when a product's temperature is changed, the "TemperatureUpdated" event is generated, which includes the batch number and the modified temperature.

As we move on to the functions' implementation, we begin with the "createProduct" function. This process is in charge of developing new products. It requires as input parameters the product name, batch number, and beginning temperature. The batch number is first verified to see if it already appears in the "products" mapping. If it does, an error notice is returned along with the function. A new Product struct is generated with the supplied information and an empty distributors array if the batch number is unique. The batch number is then used as the key to add the new product to the "products" mapping. Additionally, to keep track of the overall number of products, the "productCount" variable is increased. The "ProductCreated" event is then dispatched with the pertinent information.

The distribution of a product to a distributor is handled by the following function, "distributeProduct." It requires two parameters: the product's batch number and the distributor's address. The first thing the function does is see if the batch number is present in the "products" mapping. The function reverts with an error message if it doesn't. The distributor's address is added to the distributors array of the associated product in the "products" mapping if the batch number is valid. The batch number and distributor's address are then provided in the "ProductDistributed" event that follows.

The "updateTemperature" function, which allows updating of a product's temperature, is the last one. It requires the new temperature as well as the product batch number as input parameters. The first thing the function does is see if the batch number is present in the "products" mapping. If not, an error message is returned. If the batch number is correct, the new temperature value is added to the temperature property of the relevant product in the

"products" mapping. Last but not least, the batch number and the new temperature are included in the "TemperatureUpdated" event that is sent out.

Architecture:

transparency in the management of the supply chain for medical products.

The "Product" struct, which stands in for a health product, is the contract's main building block. It contains details like the product name, batch number, temperature, the address of the producer, and a variety of distributor addresses. The data structure used to handle and store information about specific health items is this struct.

The contract makes use of a mapping termed "products" to make data storage and retrieval easier. Each distinct batch number is linked to a corresponding Product object via this mapping. The contract can quickly retrieve the relevant

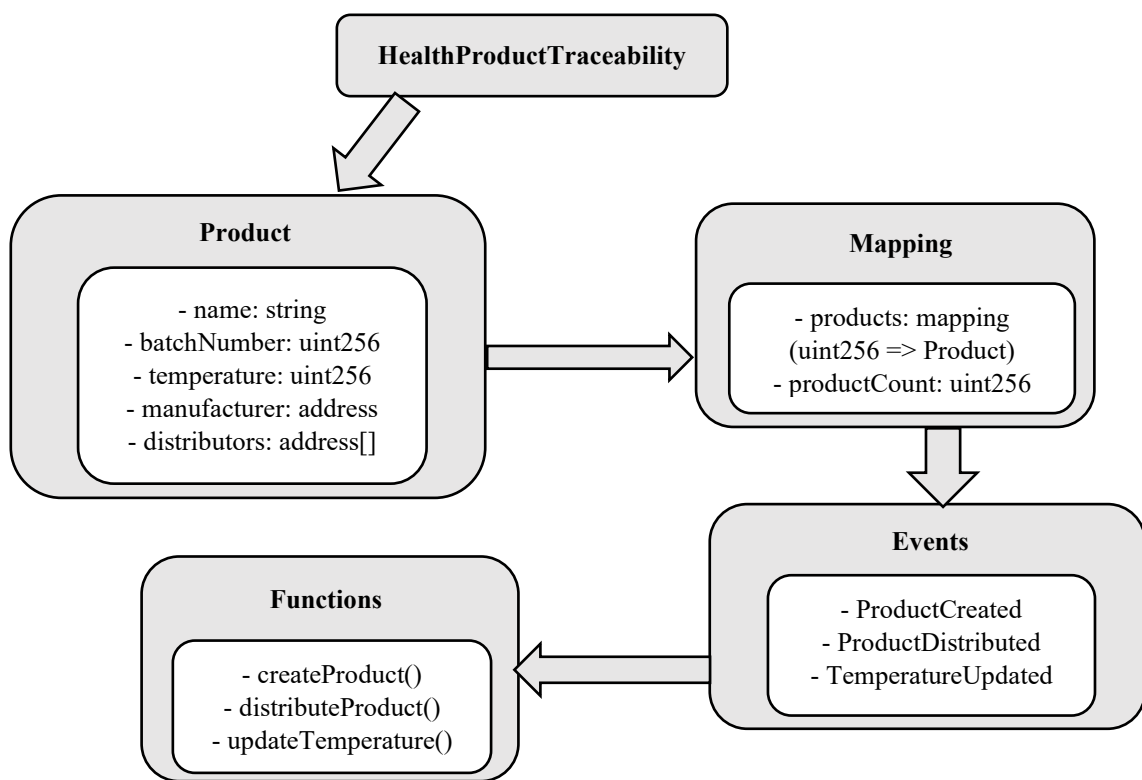


Fig.1: Architecture of Traceability on the Blockchain

product information by utilising a specified batch number to access the "products" mapping. Additionally, the contract contains a "productCount" public state variable.

The total amount of goods produced under the contract is tracked by this variable. It makes tracking the total number of products straightforward and might be helpful for reporting or statistical analysis.

The contract uses three events—"ProductCreated," "ProductDistributed," and "Temperature Updated"—to implement event-driven programming. These events are generated at specified times during the contract's execution sequence to deliver pertinent data regarding product

Explanation:

The decentralised architecture of the contract is put into practise on the Ethereum blockchain using the Solidity programming language. It makes use of the blockchain technology at the foundation to enable traceability and

creation, distribution, and temperature adjustments to outside applications or users. A new health product is made using the "createProduct" function. It requires as input parameters the product name, batch number, and beginning temperature. The contract determines whether the supplied batch number is already present in the "products" mapping within this function. In the event that it isn't, a fresh Product object is made, initialised with the supplied data, and added to the mapping. After that, the "productCount" variable is increased, and the "ProductCreated" event is fired to let other parties know that a new product has been created.

A health product can be distributed to a specific distributor using the "distributeProduct" function. It requires as input parameters the product's batch number and the distributor's address. This function checks to see if the batch number supplied is present in the "products" mapping. If it does, the address of the distributor is added to the product's "distributors" array. This makes it possible to follow the chain of distributors connected to a specific product. For the purpose of notifying external systems of the distribution activity, the "ProductDistributed" event is released.

A health product's temperature can be updated using the "updateTemperature" function. The product's batch number and the new temperature value are inputs. It checks to see if the given batch number is present in the "products" mapping, just like the earlier functions. If it does, the relevant product's temperature property is updated. Real-time monitoring of temperature changes along the product's route is made possible by this feature. To inform external systems of the temperature change, the "TemperatureUpdated" event is released.

The contract's architecture places a strong emphasis on using blockchain technology to improve trust and transparency in the traceability of medical products. The contract does away with the necessity for centralised authorities and middlemen by utilising the decentralised structure of the blockchain. As a result, all parties can access and verify product-related information without depending on a centralised authority, fostering a trustless environment.

Data about health products are preserved in an unchangeable, tamper-proof manner thanks to the incorporation of blockchain technology. Information about a product that has already been developed is permanently kept on the blockchain and cannot be changed later. This guarantees the consistency and veracity of the product data during the course of its life.

The contract design also makes it possible to track and monitor health items in real-time. A product's complete supply chain journey may be tracked by stakeholders because to the contract's ability to record temperature updates and distributor activity on the blockchain. This improves responsibility, visibility, and the capacity to recognise possible problems or hazards.

The contract complies with industry standards and protocols to ensure greater interoperability and compatibility with current systems. In order to facilitate smooth integration with other systems and stakeholders, it

emphasises the significance of standardised data formats, communication protocols, and ontologies. This strategy promotes information transmission between various platforms and supply chain networks while ensuring interoperability.

The integration of other technologies, such as IoT and AI, is highlighted by the contract architecture. Real-time data, such as temperature, humidity, and position, can be stored and captured by connecting IoT devices to the blockchain. This makes it possible for the supply chain to be monitored for health items in a more precise and detailed manner. The acquired data can be subjected to enhanced analysis, anomaly detection, and predictive insights using AI and ML algorithms, improving decision-making processes and mitigating risks.

In conclusion, the "HealthProductTraceability" smart contract's architecture makes use of blockchain technology to improve traceability and transparency in the management of the supply chain for health products. It makes use of mappings for data storage, a struct-based data model, and event-driven programming for external communication. The contract architecture offers a solid framework for enhancing health product traceability and supply chain management by embracing industry standards, integrating IoT and AI technologies, and tackling scalability and privacy problems.

Results:

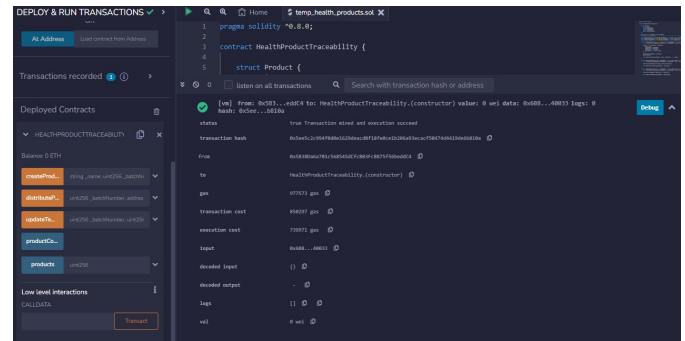


Fig.2: User interface demonstrating the deployed smart contract

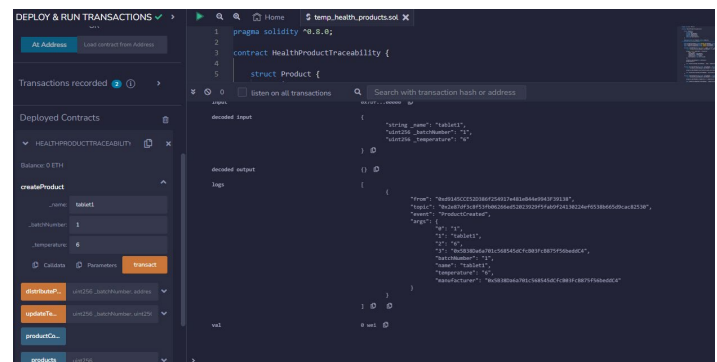


Fig.3: User interface demonstrating createProduct function

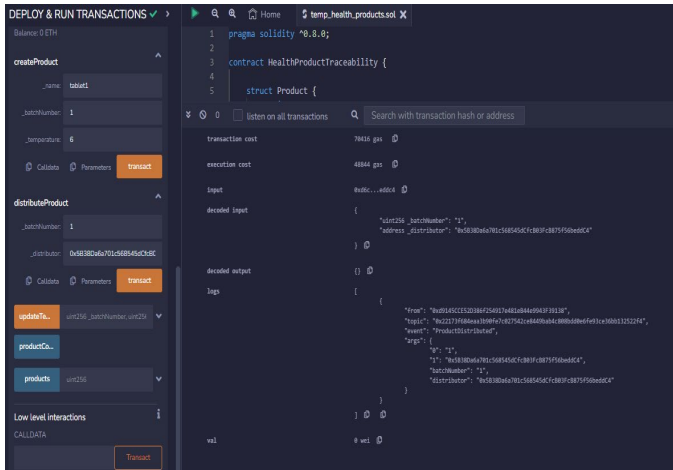


Fig.4: User interface demonstrating distributeProduct function

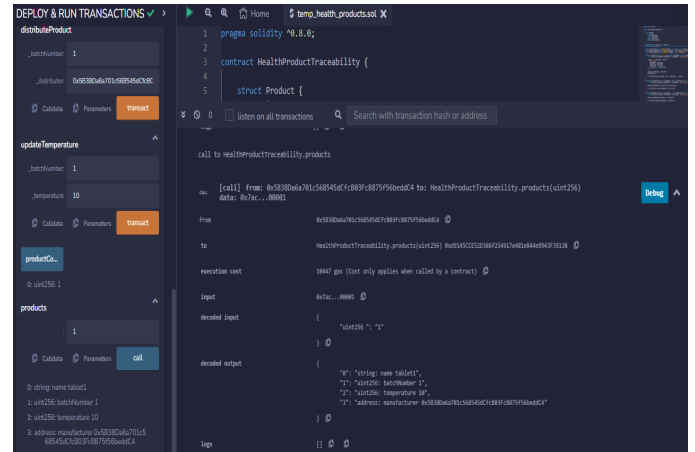


Fig.7: User interface demonstrating Products function

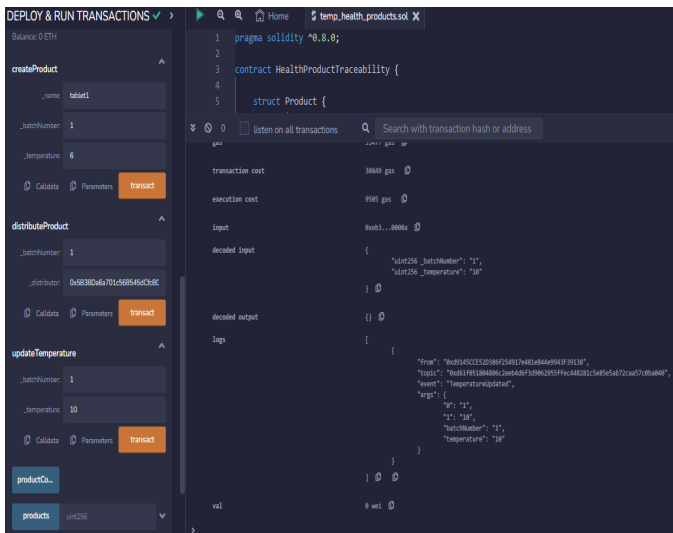


Fig.5: User interface demonstrating updateTemperature function

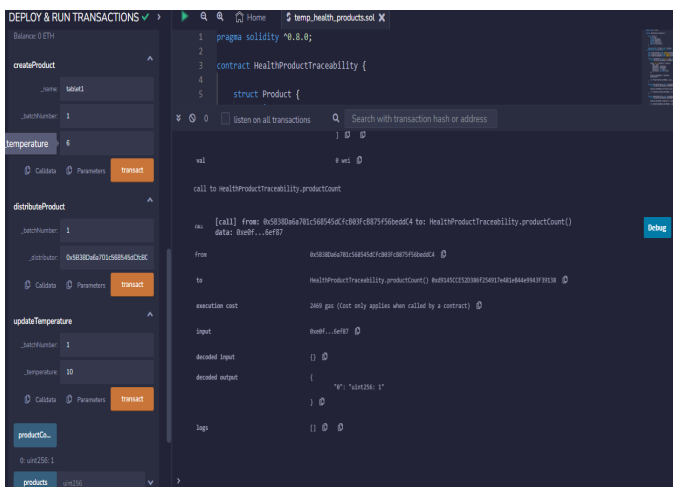


Fig.6: User interface demonstrating ProductCount function

Conclusion:

This research article presents a revolutionary method for tracking down health products that uses a smart contract built on the blockchain. Health items can be tracked securely and openly using the "HealthProductTraceability" contract, which provides vital details including batch numbers, temperature logs, manufacturers, and distributors. This study's use of blockchain technology to improve traceability in the supply chain for health products is one of its major achievements. This contract guarantees the accuracy and transparency of product data by utilising the decentralised consensus mechanism and the immutable properties of blockchain. Since there is no longer a requirement for a central authority, there is less chance of data manipulation and reliable product verification is made possible. An other notable innovation is the inclusion of events within the smart contract. These events, such "ProductCreated," "ProductDistributed," and "TemperatureUpdated," offer an effective means to transmit crucial information and enable external systems or applications to listen for these events and take suitable action. The traceability system's integration and interoperability capabilities are improved by this event-driven architecture. The contract also includes a number of crucial elements that boost the traceability solution's overall efficacy. The batch numbers are guaranteed to be unique by the product production mechanism, preventing duplication and facilitating precise identification. In addition to keeping an auditable record of distribution events, the distribution function enables the seamless transfer of items to authorised distributors. The temperature update function also makes it possible to monitor product conditions in real-time, ensuring that storage and transportation regulations are followed. This study addresses the problems with information integrity, transparency, and accountability by offering a novel method for health product traceability. This system provides a secure and decentralised method for tracking and monitoring health items through the use of blockchain technology and the implementation of a smart contract,

thereby improving consumer safety and regulatory compliance in the healthcare sector. The proposed approach creates possibilities for more study and advancement in the area of blockchain-based supply chain management and lays the groundwork for developing reliable and scalable traceability systems across diverse industries.

Future Scope:

A basis for enabling health product traceability on the blockchain is provided by the provided Solidity code for the HealthProductTraceability smart contract. In order to increase the system's functionality and efficiency, this study paper examines possible advancements and future possibilities. Future study might concentrate on improving the contract's security and access control systems. Authentication or permission management are currently absent from the contract, which could present security problems. The security of the contract would be improved and unauthorised access or changes to product data would be prevented by researching and implementing strong access control mechanisms, like role-based access control or multi-signature authentication. The incorporation of additional data sources to validate and verify the accuracy of the product information contained on the blockchain is another intriguing area for investigation. Utilising IoT devices or external APIs, for instance, to gather real-time data on product temperature, expiration dates, or quality parameters, can increase confidence and transparency. The accuracy and dependability of the information captured can be increased by including these external data sources into the contract and putting validation mechanisms in place. The contract can also be expanded to add more in-depth tracking and auditing tools. Currently, it merely records the addresses of the manufacturer and distributors; but, by adding more details, such as timestamps of product transfers or information on the recipient, the supply chain may be seen in greater detail and transparency. A more effective traceability system would result from looking for ways to include this information into the contract, such as by using event logs or external oracles. Finally, it is crucial to take into account the legal and regulatory implications of health product traceability. It is possible to ensure that the contract is compliant with regulatory frameworks by conducting research on the current laws and compliance standards at the national and international levels. The contract's usability and relevance within the legal context can be improved by looking into ways to enforce compliance through smart contract logic or interacting with external compliance verification technologies. In order to improve the HealthProductTraceability smart contract, this research paper concludes by outlining a number of potential future research areas. Enhancing security and access control mechanisms, incorporating external data sources for validation, enhancing tracking and auditing capabilities, maximising scalability, enhancing user experience, and taking regulatory compliance needs into

account are a few of these. By looking into these topics, academics can help build stronger and more useful blockchain-based health product traceability systems.

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