Ownership Management System Using Blockchain

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***Abstract*—Blockchain technology represents a cutting-edge solution for recording digital transactions in a secure, consistent, and verifiable manner, addressing challenges across various sectors. Within the supply chain domain, it enhances traceability, ownership verification, and trust among stakeholders. Additionally, blockchain provides a robust approach to mitigating counterfeit issues within supply chain networks. Despite its advantages, blockchain-based supply chains face challenges, as the rapid growth in global supply chains has increased the demand for efficient systems to ensure transparency, traceability, and security in product ownership. This study proposes a novel Ownership Management System (OMS) that leverages blockchain technology integrated with the InterPlanetary File System (IPFS) for decentralized and secure data storage. The OMS aims to combat counterfeiting by establishing verifiable proof of ownership and ensuring data privacy.**

Key contributions include the development of blockchain-based algorithms for recording product creation, ownership transfers, and traceability across the supply chain. By utilizing IPFS, the system enables scalable off-chain storage of sensitive data while maintaining data integrity through blockchain-anchored cryptographic hashes. This approach minimizes on-chain storage limitations and enhances system efficiency.

The proposed OMS ensures that end-users can verify product authenticity and reject counterfeit items even with misleading physical identifiers. With the integration of IPFS for privacy-preserving traceability, the system provides robust anti-counterfeit mechanisms applicable in industries such as pharmaceuticals, luxury goods, and electronics. This framework addresses critical challenges of scalability, privacy, and security, offering a reliable solution for modern supply chain complexities.

***Index Terms*—Blockchain, Supply chain, Counterfeits, IPFS, Privacy**

I. Introduction

Blockchain, also known as distributed ledger technology (DLT)[1], is designed to support verification-driven transaction services within a generally un-trusted ecosystem. The design of blockchain technology ensures that no one business entity can modify, delete, or even append any record to the ledger without consensus from other network participants, ensuring the immutability of data stored on the ledger. Blockchain is now being used in several industry applications such as blockchain-enabled traceability and provenance for food safety[2] documentation and cross- organization workflow management in trading and logistics [3].

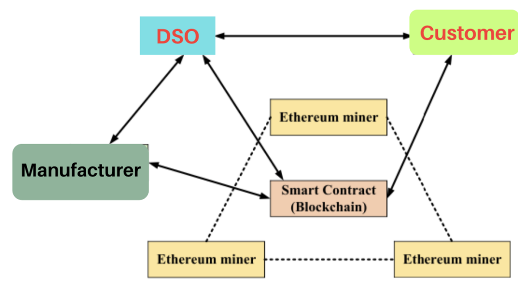

Fig. 1: Basic Working Model of Supply Chain[2]. This model describes the working of Supply Chain System in a concise way.

Today, supply chains play a crucial role for companies that transport products between different parties as shown in the model described in *Fig.1*. These chains can involve numerous layers, span across global locations, include various invoices and payments, and involve many individuals and organizations over long periods of time. The figure 2 is the *structure of the Supply Chain*. A century ago, supply chains were easier to manage because trade was mostly local. However, modern supply chains have become highly complex. For consumers, verifying the authenticity of a product is challenging due to the lack of transparency. Similarly, investigating supply chains for unethical or illegal practices is difficult. This lack of transparency and traceability leads to counterfeit products circulating in the supply chain, creating serious issues.

An assessment by the world health organization (WHO) highlighted that 10 percent of drugs sold in low- and middle-income nations were counterfeits or below acceptable standards [4].

A blockchain-based supply chain might cause privacy risks. Considering the privacy issue, a blockchain-based supply chain system is designed in the proposed work. In our work, a novel approach is proposed to introduce the privacy of transaction data with the inclusion of traceability and ownership. We propose a novel Ownership management system (OMS) for anti-counterfeits that can be used in the post supply chain.

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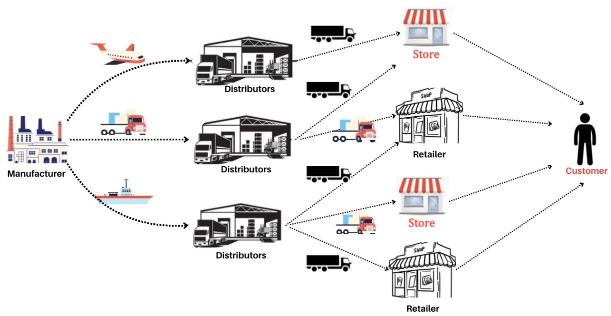

Fig. 2: Structure of the Post Supply Chain[5]. This structure describes the different levels where connection is needed.

For this purpose, we leverage the idea of Bitcoin's blockchain that anyone can check the proof of possession of balance. With the proposed OMS, a customer can reject the purchase of counterfeits even with genuine tag information, if the seller does not possess their ownership.[5]

Our contribution

The main contributions of this paper are summarized as follows:-

- A new method has been introduced to ensure the privacy of transaction data while incorporating traceability and ownership within a blockchain-based supply chain.
- Blockchain-based(Ethereum) algorithms, from product creation, to transfer the ownership of the product, and to trace the product through the supply chain with the encrypted ledger, are designed.

The work contains the following sections

1) Literature Survey
2) Preliminaries
3) Technologies
4) Proof Of Implementation
5) Conclusion

II. Literature Survey/Related Work

In the digital age, managing ownership records securely and efficiently has become a significant challenge across various industries, including real estate, supply chains, intellectual property, and digital assets. Traditional ownership management systems often face issues such as fraud, data tampering, lack of transparency, and inefficiencies caused by intermediaries. To address these challenges, blockchain technology offers a revolutionary solution by providing a decentralized, immutable, and transparent framework for managing ownership records.

The Ownership Management System Using Blockchain leverages the key features of blockchain, such as distributed ledgers, smart contracts, and cryptographic security, to create a robust system for recording, verifying, and transferring ownership. By eliminating the need for intermediaries and ensuring data integrity, this system enhances trust among stakeholders while reducing operational costs and delays. Furthermore, it introduces traceability and accountability, making it easier to track ownership histories and resolve disputes effectively.

Public blockchains specifically designed for tracking supply chain systems, such as Vechain and Waltonchain, tend to have lower throughput and higher transaction fees compared to other high-performance public blockchains that are not focused on supply chain systems, such as Polygon, IOTA, and Solana. The average throughput of the VeChain network is 165 TPS [6]. In contrast, the Waltonchain network throughput is approximately 13.5 TPS[7]. The network latency, i.e., block generation time in this case, of VeChain is 10 s and around 30.73 s for Waltonchain. These network latencies are quite high compared to the high-performance public blockchains.

Blockchain technology has the potential to revolutionize the supply chain due to its desirable features, including traceability, transparency, and accessibility. These characteristics are drawing significant interest from supply chain industries, particularly in the food, agriculture, and pharmaceutical sectors [8][9][4, 5]. The current supply chain infrastructure relies on a centralized cloud repository managed by third parties, which poses risks such as data breaches of sensitive information, lack of security, limited visibility, and privacy concerns. To address the issue of counterfeiting, researchers propose updating the ownership details of products on the blockchain as they move through the distribution network. RFID (Radio Frequency Identification) tags can be utilized to update information during transfers between different entities or to store ownership details during each phase of transit [10]. If a product's history lacks ownership data for the vendor from whom the customer made a purchase, the item may be returned upon arrival at the store. Additionally, information about the origins of raw materials used in production can be retrieved, offering an effective means of conducting quality checks from the producer to the end consumer [11].

Caro et al. [12] introduced a decentralized solution called AgriBlockIoT, which combines blockchain technology with IoT. The AgriBlockIoT system architecture involves key stakeholders such as providers, producers, distributors, retailers, and consumers. This architecture is supported by an application programming interface (API) that integrates IoT and blockchain to enhance the agricultural food supply chain. However, the authors do not recommend any specific data privacy algorithm.

Lin et al. [13] proposed a decentralized supply chain system based on the EPCIS (Electronic Product Code Information Services) network and Ethereum blockchain to address the challenge of data explosion. Their proposed system employs a hybrid on-chain and off-chain data management model to improve performance. The authors also emphasize the importance of data privacy.

III. Preliminaries

A. Blockchain Technology

Blockchain technology has emerged as a transformative solution in supply chain management due to its ability to enhance transparency, traceability, security, and efficiency. In the supply chain context, blockchain is a distributed ledger that records every transaction or movement of goods in a

decentralized, immutable, and transparent manner. This creates a single source of truth that all stakeholders can trust without relying on intermediaries.
Key Characteristics of Blockchain

- Decentralization: Blockchain eliminates the need for a central authority or intermediary by allowing peer-to-peer transactions between supply chain participants. This reduces operational inefficiencies and costs.
- Immutability: Every transaction recorded on the blockchain is permanent and tamper-proof. This ensures the authenticity of records and prevents fraudulent activities.
- Transparency: All stakeholders can access real-time information about the supply chain. This visibility enhances trust and accountability across the network.
- Traceability: Blockchain enables end-to-end tracking of products from their origin to the final consumer. This helps identify and resolve issues such as counterfeiting, delays, or quality concerns.
- Automation through Smart Contracts: Smart contracts—self-executing contracts with terms directly written into code—can automate processes such as payments, order verification, and delivery updates, reducing human intervention and errors.

Blockchain systems are generally classified into three types: public blockchains, consortium blockchains, and private blockchains [30]. Public blockchains are permissionless, whereas both consortium and private blockchains fall under the category of permissioned blockchains. In public blockchains, anyone can join the network, take part in the consensus process, read or send transactions, and maintain the shared ledger. Most cryptocurrencies and some open-source blockchain platforms operate as permissionless systems. Representative public blockchain systems include Bitcoin [14] and Ethereum [15], [16]. Bitcoin, created by Satoshi Nakamoto in 2008, is the most famous cryptocurrency. Ethereum is another prominent public blockchain that enables extensive decentralized applications through its Turing-complete smart contract programming languages.

Consortium blockchains are typically used in business environments to record cross-organizational transactions. Unlike public blockchains, consortium blockchains restrict participation in the consensus process to authorized entities. Private blockchains, on the other hand, are distributed networks owned by a single organization or entity, making them centralized to some degree. Permissioned blockchain systems can be further categorized as public or private permissioned blockchains. Both types restrict the ability to participate in the consensus process, send transactions, and maintain the ledger to authorized entities. However, public permissioned blockchains allow anyone to read the ledger's transactions, whereas private permissioned blockchains limit this ability to authorized entities. Most business-oriented blockchain systems fall into the permissioned category. Hyperledger Fabric [17] is a prominent example of a permissioned blockchain system.

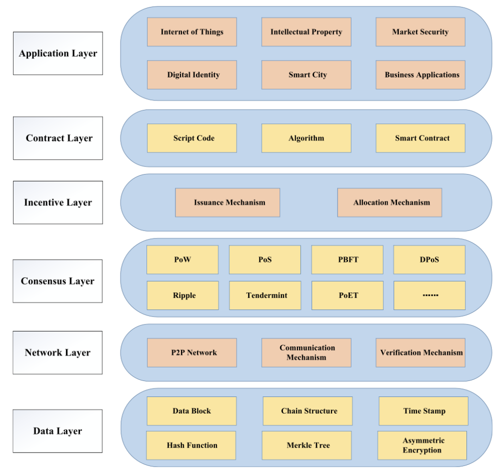

Fig. 3: A general blockchain architecture[18][19] . The data layer encapsulates the time-stamped data blocks. The network layer is composed of distributed networking mechanism, data propagation mechanism and data verification mechanism. The consensus layer consists of various consensus algorithms. The incentive layer is the main driving force for blockchain network. The contract layer brings programmability into blockchain. The application layer is composed of blockchain-based business applications.

B. Architecture of Blockchain

A blockchain architecture consists of six main layers: the data layer, network layer, consensus layer, incentive layer, contract layer, and application layer [18][19], [20], [21] as shown in Fig. 3. The lowest layer in blockchain architecture is the data layer, which encapsulates the time-stamped data blocks. Each block contains a small part of transactions and is "chained" back to its previous block, resulting an ordered list of blocks [22]. A typical block structure [18], [19], [23] is shown in Fig. 4. The data layer is the foundation, comprising time-stamped data blocks connected in an ordered chain. The block structure mainly includes two parts: the block header and the block body. The block body stores verified transactions. The block header specifies the metadata, including hash of previous block, hash of current block, timestamp, Nonce and Merkle root. The hash of previous block is used by the current block to connect its previous block called parent block. The first block of a blockchain is named as genesis block that has no parent block. Timestamp indicates the creating time of this block. Nonce relates to mining process. The Merkle root is the root of a Merkle tree. The Merkle tree uses a hash binary tree to store the transactions within a specific time period. In this way, the existence and integrity of transactions can be verified rapidly, efficiently and securely.
The network layer facilitates transaction distribution, forwarding, and verification in a P2P network. Transactions are broadcast to nodes, verified, and either forwarded or discarded. Digital signatures based on asymmetric cryptography ensure

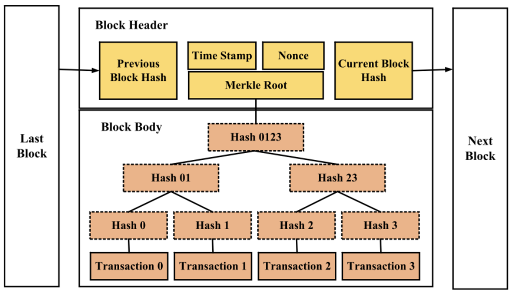

Fig. 4: A typical block structure[18], [19]. The block structure mainly includes two parts: block header and block body. The block body stores verified transactions. The block header specifies the metadata, including hash of previous block, hash of current block, timestamp, Nonce and Merkle root.

authentication, where the private key signs transactions, and the public key verifies them.

The consensus layer achieves agreement among decentralized nodes before a block is added to the chain. Popular consensus mechanisms include Proof of Work (PoW), Proof of Stake (PoS), Delegated Proof of Stake (DPoS), and Practical Byzantine Fault Tolerance (PBFT). PoW relies on computational effort to generate a nonce, while PoS selects validators based on stake. DPoS delegates validation to elected representatives. PBFT ensures fault tolerance in permissioned blockchains. Additional mechanisms include Ripple, Stellar, Tendermint, and Proof of Elapsed Time (PoET), among others [14], [24].

The incentive layer integrates economic factors to reward participants for contributing to the network. For instance, miners or validators receive digital currencies for generating valid blocks .

The contract layer introduces programmability using smart contracts, which automate processes based on predefined conditions. Smart contracts, written in programming languages like Solidity, are cryptographically signed, verified, and executed automatically. Ethereum supports Turing-complete languages, enabling complex decentralized applications. Other systems like Tezos and Corda provide more secure, non-Turing complete languages [25].

The application layer includes real-world use cases, such as IoT, intellectual property management, market security, and digital identity. Blockchain enables innovative services and business optimizations across various domains, despite being in its early stages [26].

The blockchain workflow starts with transaction creation, signing using private keys, and broadcasting to neighboring nodes. Valid transactions are added to the network, bundled into blocks, and validated through a consensus mechanism like PoW. Once verified, the block is appended to the chain and distributed across the network [14].

C. *Ethereum*

Ethereum is a major blockchain-based platform for smart contracts – Turing complete programs that are executed in a decentralized network and usually manipulate digital units of value. A peer-to-peer network of mutually distrusting nodes maintains a common view of the global state and executes code upon request. The stated is stored in a blockchain secured by a proof-of-work consensus mechanism similar to that in Bitcoin. The core value proposition of Ethereum is a full-featured programming language suitable for implementing complex business logic. Decentralized applications without a trusted third party are appealing in areas like crowdfunding, financial services, identity management, and gambling. Smart contracts are a challenging research topic that spans over areas ranging from cryptography, consensus algorithms, and programming languages to governance, finance, and law[15].

In recent years, blockchain technology has emerged as a transformative tool with significant implications for various sectors, from finance to healthcare, and supply chain management to verification of digital identity. A prominent manifestation of blockchain technology is Ethereum, an open source decentralized platform featuring smart contract functionality that enables the development and execution of decentralized applications (DApps). Since its inception in 2015, Ethereum has transformed the landscape of traditional client–server applications and services (e.g., DApps), the financial world (e.g., cryptocurrencies and Decentralized Finance DeFi in general) and the digital marketplace (e.g., non-fungible token NFT and decentralized storage services) (Buterin, 2014). With a robust programming language (i.e. Solidity) and an open-source, decentralized platform, Ethereum has gained significant attention worldwide, and it is now the second-largest cryptocurrency network after Bitcoin.

With its open ledger, Ethereum offers unparalleled transparency, where every transaction is auditable. However, this transparency does not equate to a complete loss of privacy. Users can interact with the Ethereum network through pseudonymous addresses, ensuring transactions are visible while the real-world identity of the actors remains obscured.[27]

D. *Wallet*

In recent years, technology has assumed a pivotal role across numerous sectors, including banking and financial services. The integration of financial technology(FinTech) and blockchain is actively revolutionizing digital banking services. FinTech encompasses activities leveraging innovation and technological advancements to design, deliver, and manage financial products and services. In the banking sector, FinTech has primarily influenced payment systems and transaction execution methods. Its objective in banking is to reshape profitability conditions for industries and create new revenue streams through digital payment solutions[28]. Among these innovations, cryptocurrencies represent the most disruptive force in payment services.

In this framework, cryptocurrency wallets—software applications for managing cryptocurrencies—have gained prominence alongside the rise of digital currencies. These wallets are essential tools for interacting with blockchain and cryptocurrency ecosystems. Blockchain operates as a decentralized, transparent chain of data blocks, forming a shared database accessible to users for tracking and verifying transactions. Each digital operation performed by a network user generates data stored within a block, which is subsequently linked to the blockchain. The technology's decentralized and open-source characteristics enable innovation in financial services and administrative processes, enhancing efficiency and transparency.

A MarketsandMarkets report (2022) indicates that the blockchain market was valued at *4.9 billion* in 2021 and is projected to reach *67.4 billion* by 2026, with a Compound Annual Growth Rate (CAGR) of 68.4 percent during the forecast period. Consequently, cryptocurrency wallets provide a secure mechanism for accessing and transacting on blockchain networks. These wallets are indispensable for cryptocurrency usage.

Cryptocurrency wallets are categorized into hot wallets and cold wallets. Hot wallets are internet-connected software-based solutions accessible via browsers or applications. However, because online environments are not entirely secure, funds in hot wallets may face risks such as theft or software vulnerabilities. Cold wallets, in contrast, store digital currencies offline, requiring physical devices such as USB drives, computers, or QR codes for access. These wallets, being disconnected from the internet, are safeguarded from online threats.[29]

Hot wallets include desktop wallets, web wallets, and mobile wallets, while cold wallets encompass hardware wallets and paper wallets.

E. Smart Contract

A smart contract is a self-executing digital agreement where the terms are directly written into lines of code, enabling automated and secure transactions without intermediaries. When applied to supply chain management (SCM), smart contracts powered by blockchain technology offer numerous benefits, including enhanced transparency, automation, and sustainability.
Key Benefits in SCM:

- *Automation and Efficiency:* Smart contracts automate repetitive tasks like payments, inventory tracking, and compliance checks. For instance, IoT-enabled smart containers integrated with Ethereum-based smart contracts ensure predefined conditions (e.g., temperature for vaccines) are met, triggering automated responses such as refunds for violations without manual intervention [30].
- *Enhanced Transparency:* They create immutable records of every transaction, reducing fraud and enabling real-time tracking across the supply chain. This helps businesses and stakeholders access the entire history of product movements and conditions[31].
- *Cost Reduction:* By eliminating intermediaries and enabling peer-to-peer transactions, smart contracts reduce administrative and transactional costs
- *Sustainability:* Smart contracts support sustainability by improving supply chain maturity. They facilitate sustainable procurement practices, eco-efficient operations, and lifecycle monitoring, ensuring compliance with environmental and social goals[30][31].
- *Resilience and Risk Mitigation:* Blockchain-based smart contracts help prevent disruptions by decentralizing operations and eliminating single points of failure, thereby making supply chains more resilient

F. Mining

Mining is a fundamental process in blockchain technology, primarily in networks like Bitcoin and Ethereum. It involves validating transactions, securing the network, and adding new blocks to the blockchain through computational problem-solving. Mining plays a central role in blockchain ecosystems, especially for networks using Proof-of-Work (PoW). Here's a deeper dive into its technical, economic, and environmental aspects:

1.Technical Mechanism:

- *Cryptographic Puzzle Solving:* Miners use computational power to solve a mathematical problem that involves finding a hash (a fixed-length alphanumeric code) below a target value. This requires repeatedly hashing data (modifying a "nonce" value) until the correct hash is found[32].
- *Consensus Protocols:* Mining is integral to PoW-based blockchains, ensuring consensus across decentralized networks by requiring participants to demonstrate computational effort (work) before adding a new block[33][32].

2.Economic Model:

- *Rewards and Incentives:* Miners are rewarded with newly minted cryptocurrency and transaction fees.The reward halving (e.g., Bitcoin's halving every 4 years) controls inflation and maintains scarcity[32][34].
- 2.*Economic Model:* Individual miners often join mining pools to combine computational resources, increasing their chances of earning rewards. However, large pools raise concerns about centralization risks (e.g., concentration of 51 percent of mining power)[34].

3.Energy and Environmental Impact:

- *Energy Consumption:* Mining is energy-intensive, as it requires significant computational power. Bitcoin mining alone can consume energy comparable to small nations.
- *Shift to Sustainable Mining:* Efforts are underway to use renewable energy sources, such as hydropower or geothermal energy in countries like Iceland and Canada. Alternative consensus mechanisms like Proof-of-Stake (PoS) are being adopted in some networks

(e.g., Ethereum's shift to Ethereum 2.0) to reduce energy usage[32][34].

4.Mining Equipment:

- *Hardware Evolution:* Early miners used CPUs, but the demand for higher efficiency led to GPUs and ASICs (Application-Specific Integrated Circuits). ASICs dominate today, offering terahashes per second (TH/s) capabilities but are costly and specialized[32].
- *Hash Rate:* A higher hash rate (number of hashes per second) contributes to network security but increases energy requirements[33][32].

5.Challenges and Risks:

- *Geographical Concentration:* Mining often clusters in areas with low energy costs, such as China (historically), the U.S., and parts of Europe, which creates dependencies and vulnerabilities[34].
- *Economic Volatility:* The profitability of mining fluctuates with cryptocurrency prices and block reward structures. During price drops or reward halving events, miners may exit the network, reducing security[33][34].

IV. Proof of Implementation

A. *Technologies*

1. Blockchain: The Immutable Foundation

To ensure the security, transparency, and immutability of our system, we leveraged the power of blockchain technology. We constructed a private Ethereum blockchain network, tailored to our specific needs. This blockchain served as the backbone of our application, recording all transactions and interactions in a decentralized and tamper-proof manner.

2. Smart Contracts: Automating Trust

We deployed smart contracts on our Ethereum blockchain to automate various processes and enforce predefined rules. These self-executing contracts, written in Solidity, streamlined operations and reduced the need for intermediaries. Key use cases of smart contracts in our project included:

- *Secure Data Storage:* Smart contracts were used to store cryptographic hashes of data uploaded to IPFS, ensuring data integrity and provenance.
- *Access Control:* Smart contracts implemented fine-grained access control mechanisms, allowing authorized users to interact with specific parts of the system.
- *Automated Payments:* Smart contracts facilitated automated payments and settlements, eliminating the need for manual intervention.

3. Ethereum: The Powerhouse

Ethereum provided the underlying platform for our blockchain network, offering a rich ecosystem of tools and libraries. We utilized Ethereum's virtual machine to execute smart contracts and process transactions. Key benefits of leveraging Ethereum included:

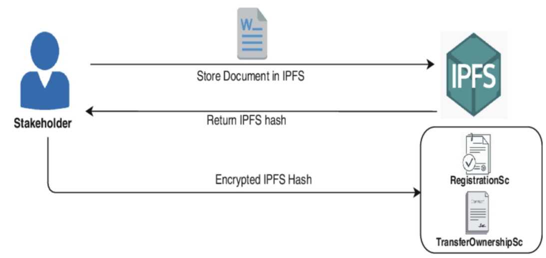

Fig. 5: Document storage in IPFS during registration and transfer[35].

- *Scalability:* Ethereum's modular architecture enabled us to scale our application to accommodate growing user demand.
- *Security:* Ethereum's robust security mechanisms, including proof-of-stake consensus, protected our network from attacks.
- *Community and Ecosystem:* The thriving Ethereum community provided access to a wealth of resources, libraries, and developer support.

4. IPFS(InterPlanetary File System): Decentralized Storage

To ensure the long-term preservation and accessibility of data, we integrated IPFS into our system. IPFS distributed data across a decentralized network of nodes as shown in Fig.5, making it resilient to failures and censorship. By storing data on IPFS, we achieved the following:

- *Data Durability:* IPFS ensured the long-term availability of data, even if individual nodes were offline.
- *Data Integrity:* IPFS's content-addressed storage mechanism guaranteed the integrity of data.
- *Reduced Storage Costs:* By leveraging the decentralized nature of IPFS, we reduced storage costs and improved efficiency.

By strategically combining these technologies, we have built a robust and innovative solution that addresses the challenges of counterfeit in the Product Ownership Management System that uses concept of the Supply chain System. Our system leverages the power of decentralization, automation, and security to deliver a superior user experience.

B. *Blockchain*

Blockchain technology, a decentralized and transparent digital ledger, has revolutionized various industries. Its unique properties, such as immutability and security, make it an ideal solution for managing ownership rights. In this paper, we will explore the core concepts of blockchain technology and its potential applications in an Ownership Management System.

Core Concepts of Blockchain
Decentralization:

- No central authority controls the network.

- Transactions are validated and recorded by a network of nodes.
- This eliminates single points of failure and increases security.

Immutability:

- Once a transaction is recorded on the blockchain, it cannot be altered or deleted.
- This ensures the integrity and authenticity of the data

Transparency:

- All transactions are visible to everyone on the network.
- This promotes trust and accountability.

Security:

- Cryptographic techniques, such as hashing and digital signatures, secure the network.
- This makes it extremely difficult for malicious actors to manipulate the data.

Blockchain in Ownership Management

A blockchain-based Ownership Management System can offer several advantages:

Enhanced Security:

- Cryptographic techniques ensure the security and integrity of ownership records.
- Unauthorized access and tampering are significantly reduced.

Increased Transparency:

- All ownership transfers and changes are recorded on the blockchain, providing a transparent and auditable history.
- This reduces disputes and increases trust among stakeholders.

Improved Efficiency:

- Smart contracts can automate many ownership management processes, such as property transfers and fee payments.
- This reduces administrative overhead and speeds up transactions.

Enhanced Privacy:

- Blockchain technology can be used to create private and permissioned networks, allowing for selective sharing of ownership information.
- This protects sensitive data while maintaining transparency within the system.

C. Ethereum and Ether

Ethereum is a decentralized blockchain platform designed for building and running smart contracts—self-executing agreements where the terms are written directly into code. It provides a robust ecosystem for developing decentralized applications (DApps). Ether (ETH) is Ethereum's native cryptocurrency, used to pay for transactions and computational resources on the network.

We have used Ethereum technology because it can be highly beneficial such as:

- *Smart Contracts for Ownership Management:* You can use Ethereum's smart contracts to securely record and manage product ownership. These contracts ensure transparency, immutability, and automation, reducing the risk of fraud.
- *Interoperability and Ecosystem Support:* Ethereum's widespread adoption and active developer community make it easier to integrate your system with other platforms or access tools, libraries, and frameworks.
- *Immutable Ledger:* Ethereum ensures a tamper-proof record of transactions, enhancing trust in your ownership management system.
- *Tokenization:* If your system involves representing products as digital assets, you can leverage Ethereum standards like ERC-721 (non-fungible tokens) for unique product ownership or ERC-1155 for flexible asset management.
- *Global Accessibility:* Ethereum's decentralized nature ensures that your system is accessible globally without relying on centralized infrastructure.

Using Ethereum makes the project future-proof, secure, and scalable, increasing its chances of success in industries such as supply chain management, luxury goods authentication, and intellectual property rights. By leveraging its technology, the solution we designed can stand out as an innovative and reliable platform.

Ether(ETH)

Ether is the native cryptocurrency of the Ethereum blockchain. In the project, Ether serves multiple purposes:

- *Payment for Gas Fees:* Users interacting with your system (e.g., transferring ownership, registering products, or querying data) will need to pay gas fees in Ether.
- *Incentivizing Miners/Validators:* Ether compensates miners (or validators in Ethereum 2.0) for validating and processing transactions, ensuring your system remains secure and operational.
- *Microtransactions:* If the system incorporates fees for specific services (e.g., priority processing or premium features), Ether can be used as the payment method.

Gas

Gas is the unit of measurement for the computational work required to perform operations on Ethereum. Each transaction or smart contract execution requires a certain amount of gas, paid in Ether. Here's how Gas plays a role in the project:

- *Transaction Execution:* When a user registers a product or transfers ownership, the required computational steps consume gas. Users pay for this gas in Ether.
- *Cost Management:* Gas ensures that computational resources are used efficiently. Users pay more for complex operations, discouraging wasteful or spammy behavior on the network.
- *Security:* Gas limits protect your project from malicious or poorly written code. If a transaction exceeds the gas limit, it's halted, preventing excessive resource consumption.

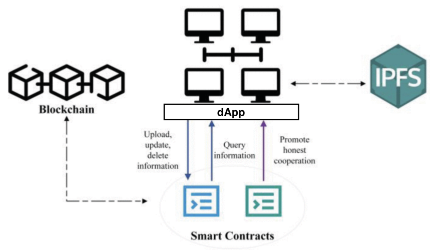

Fig. 6: Working of dApp and Decentralised Storage System in Blockchain Network[36].

- *Dynamic Pricing:* Gas prices fluctuate based on network activity. You can design your system to optimize gas usage, reducing costs for users.

D. *dApp*

A *decentralized application* (dApp) is a blockchain-based software system that operates on a peer-to-peer network, ensuring autonomy, transparency, and security. Unlike traditional applications, dApps leverage distributed ledger technology (DLT) to execute smart contracts, enabling decentralized and tamper-proof operations as shown in *Fig.6*. These features make dApps ideal for use in supply chain management, where transparency, traceability, and trust are critical.
Key Features of dApps in Supply Chain :-

1) *Traceability and Authenticity:* dApps create immutable records of product provenance, ownership, and transaction history, ensuring data integrity and combating counterfeiting[37][38].
2) *Transparency and Accountability:* All stakeholders have real-time access to supply chain data, improving compliance and reducing disputes[37][39].
3) *Efficiency and Automation:* Smart contracts automate tasks such as payment processing, order validation, and shipment tracking, reducing delays and operational costs[39][38].
4) *Decentralization and Security:* By distributing data across multiple nodes, dApps eliminate single points of failure, enhancing system resilience against attacks[37][40].

In our project, a dApp is implemented to manage product ownership throughout the supply chain. Here's how it works :

- *Product Registration:* Manufacturers register each product on the blockchain, associating it with a unique identifier (e.g., serial number).
- *Ownership Tracking:* As products move through the supply chain, ownership and transaction details are recorded on the dApp. Smart contracts enforce rules such as transfer conditions or warranties.
- *Counterfeit Detection:* By scanning the product's identifier, stakeholders (including end consumers) can verify its authenticity using the blockchain record[37][38].
- *Transparency for Audits:* Regulators or partners can access immutable transaction logs to ensure compliance with standards or resolve disputes[38].
- *Integration with IoT:* IoT devices can update the dApp in real-time, recording environmental conditions or location data to monitor product quality during transit[37][40].

A dApp-based system enhances trust among stakeholders, reduces inefficiencies, and addresses challenges like counterfeiting and fraud. For instance, Ethereum-based supply chain dApps have been used to track food products, ensuring origin traceability and quality compliance[39][40]. Our project aligns with these innovations, creating a practical application that integrates with existing supply chain systems while leveraging blockchain for enhanced security and efficiency. Addressing challenges such as scalability, regulatory compliance, and user adoption will ensure the success and scalability of our project[39].

E. *Decentralised Storage System (IPFS)*

Decentralized storage applications have gained traction as individuals seek more secure and private methods for data storage. These systems are designed to replace centralized storage solutions that are vulnerable to data breaches, cyberattacks, and theft. The *Fig.7* shows the conceptual model of Centralized and Decentralized storage application and their working styles. By utilizing blockchain technology and a network of distributed nodes, decentralized storage applications offer a more secure and private way to store and share data. A major benefit of these applications is the ability to access and share data directly, without intermediaries, empowering users with greater control over their information and reducing the risks of unauthorized access or data breaches. Furthermore, decentralized storage is highly scalable, allowing for efficient storage and retrieval of vast amounts of data without the need for expensive infrastructure.

When combined with blockchain technology and IPFS (InterPlanetary File System), decentralized storage enhances data security, speeds up file retrieval, and ensures better data availability through these key mechanisms:

Enhanced Data Security: Blockchain provides a decentralized platform for data storage and sharing, ensuring that data is not controlled by a single entity, which reduces the risk of centralized failures and external threats. The use of cryptographic techniques also strengthens data security, making unauthorized access far more difficult.

Quicker File Retrieval: IPFS offers a distributed file system that allows files to be split into smaller parts and stored across multiple nodes. This approach results in faster file access with lower latency, enhancing the overall speed and efficiency of data retrieval.

Improved Data Availability: Traditional centralized file storage is vulnerable to outages and data loss due to single points of failure. In contrast, IPFS and blockchain technology distribute data across a network of nodes, ensuring that files remain accessible even if one node goes offline, which increases data availability and reliability.

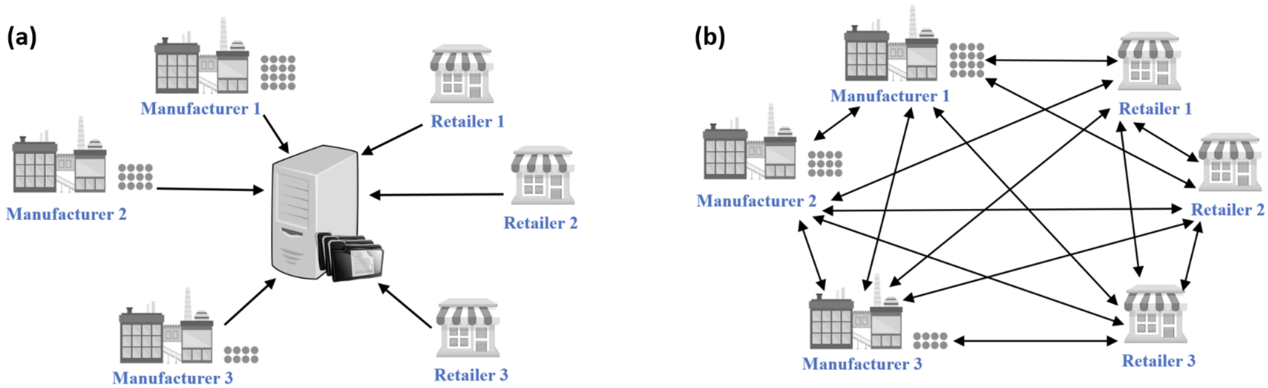

Fig. 7: This figure shows the types of storage pattern **a.**Centralized and **b.**Decentralized[41].

An additional benefit of decentralized storage is its ability to safeguard privacy and confidentiality. Unlike centralized solutions, which store data on single servers, decentralized applications spread data across multiple locations, making it more difficult for hackers to breach or steal sensitive information. As decentralized storage continues to evolve, its adoption is likely to expand, becoming a more integral part of the digital infrastructure in the future.

The Key Features of IPFS :-

- Content-Based Addressing: Files are addressed by their unique cryptographic hash rather than a location-based address (e.g., a URL). This ensures content immutability, as any change in the file results in a new hash.
- Decentralization: By distributing data across multiple nodes, IPFS eliminates single points of failure and improves data availability and fault tolerance.
- Data Deduplication: IPFS stores only unique chunks of data, making it highly efficient in terms of storage.
- Versioning and Persistence: IPFS supports versioning and pinning mechanisms to retain specific files on the network, allowing users to manage file availability.
- Interoperability: IPFS seamlessly integrates with blockchain networks and decentralized applications (dApps), making it a perfect candidate for distributed systems like supply chains.

Using IPFS in our ”Ownership Management System” offers several advantages :-

- *Scalability:* IPFS offloads data from the blockchain, ensuring that the system remains scalable as the number of transactions grows.
- *Cost-Efficiency:* By storing only file hashes on-chain, storage costs are minimized while maintaining data integrity and accessibility.
- *Resilience:* The decentralized nature of IPFS ensures that product-related data remains accessible even if some nodes in the network go offline.
- *Security and Trust:* The cryptographic hashing mechanism guarantees data authenticity and integrity, fostering trust among supply chain stakeholders.
- *Gobal Accessibility:* As a peer-to-peer network, IPFS ensures that data can be accessed from anywhere in the world without relying on centralized infrastructure.

Challenges and Considerations :-

- *Data Persistence:* To ensure that files remain available on IPFS, a mechanism like ”pinning” must be implemented, either using IPFS nodes or a third-party pinning service (e.g., Pinata).
- *Performance:* Retrieval times in IPFS can be slower than traditional centralized systems, particularly for less-accessed files.
- *Integration Complexity:* Seamless integration of IPFS with blockchain systems requires careful architectural planning to ensure security and efficiency.

Incorporating IPFS into our blockchain-based Ownership Management System provides a decentralized, secure, and efficient solution for managing and sharing product data. It complements blockchain’s strengths by addressing its storage limitations, enhancing traceability, and enabling seamless collaboration across supply chain stakeholders. By leveraging IPFS, our project ensures that the supply chain becomes more transparent, tamper-proof, and future-ready.

F. Smart Contract

A Smart Contract is a self-executing program stored on a blockchain, where the terms of an agreement between stakeholders are directly written into lines of code. These contracts automate processes, enhance transparency, and ensure trust in decentralized systems. In this project, the smart contract is designed to manage product ownership seamlessly across manufacturers, distributors, retailers, and customers while leveraging blockchain’s immutability and security.

This project implements a *”Product Ownership Management System”* using a smart contract that ensures the authenticity and traceability of products through their lifecycle, from manufacturing to the end customer. It eliminates the risks of counterfeit products by securely storing all transactions and

ownership data on the blockchain.
Some of the Functions Used in the Smart Contract are:-

- *registerStakeholder(StakeholderType type, string memory name) :* It allows users to register themselves as one of the four stakeholder types: Manufacturer, Distributor, Retailer, or Customer.
- *registerProduct(string memory productId, string memory name, uint quantity) :* It enables manufacturers to register new products on the blockchain.
- *transferProduct(string memory productId, address to) :* Transfers product ownership from one stakeholder to another.
- *updateReputation(address stakeholder, uint newScore) :* Updates the reputation score of a stakeholder based on their performance or feedback.
- *getInventory(address owner) :* It retrieves the list of products currently owned by a specific stakeholder.

G. ***Transactions***

Transactions in a supply chain ownership management system represent the critical operations that facilitate the transfer, validation, and traceability of products across various stakeholders. Leveraging blockchain technology ensures transparency, immutability, and accountability in these processes. The primary types of transactions in this system include product creation, ownership transfer, and traceability verification as shown in *Fig.8*. Below is the detailed explanation:

- Registration Transactions

  1. Participants Involved: Manufacturers, Distributors, Retailers, and Customers.
  2. Process: Each participant in the supply chain must register using the *RegisterManufacturer()*, *RegisterDistributor()*, and *RegisterRetailer()* functions. The registration is validated using smart contracts stored on the blockchain network, ensuring only authenticated entities can access the system. These smart contracts are associated with a unique identification (e.g., hashed document identifiers) for every stakeholder.
  3. Output: Successful registration allows participants to create and manage inventory and transactions. The decentralized nature ensures that registration data is securely stored and immutable.

- Product Creation Transactions

  1. Participants Involved: Manufacturer, Blockchain Network.
  2. Process: A manufacturer registers a product in the system using the *addItem()* function. Details such as product name, ID, and quantity are hashed and stored on the blockchain via IPFS (InterPlanetary File System). Notifications are sent to all stakeholders about the addition of the product.
  3. Output: The product details become traceable across the supply chain. Every transaction is recorded as an immutable block in the blockchain.

- Ownership Transfer Transactions

  1. Participants Involved: Manufacturer, Distributors, Retailers, Customers.
  2. Process: Ownership of products is transferred using the *Transfer()* function. *For example:* A manufacturer ships a product to a distributor using the *Ship()* function. The distributor receives the product and can further transfer ownership to the retailer. Each transfer involves a check of the product's hash code for validation. Smart contracts validate the transfer and update the blockchain.
  3. Output: All stakeholders are notified about the ownership change. The product's current owner is updated in the blockchain, ensuring traceability.

- Inventory Management Transactions

  1. Participants Involved: All stakeholders.

  2. Process : Stakeholders can update their inventory using the *addItem()* function. Each update triggers the blockchain to verify the availability and source of the product. Stakeholders are notified when inventory details are updated, ensuring synchronization across the network.

  3. Output: Real-time updates on inventory status. Prevention of discrepancies in stock management.

- Traceability Transactions

  1. Participants Involved: All stakeholders, particularly customers.
  2. Process: Customers or stakeholders can verify the origin and ownership history of a product using the *checkOwner()* function. The hash code of the product is validated against blockchain records to retrieve ownership and transfer details.
  3. Output: Enhanced customer trust by ensuring product authenticity. Quick access to a tamper-proof ownership history.

- Reputation and Feedback Transactions

  1. Participants Involved: All stakeholders.

  2. Process: After a transaction, stakeholders can provide feedback using a reputation score mechanism embedded in smart contracts. These scores are added to the blockchain and contribute to the overall trustworthiness of the stakeholders.

  3. Output: A decentralized rating system for evaluating supply chain participants. Incentives for maintaining high performance and trustworthiness.

H. ***Working of the Model***

We have developed a Product Ownership Management System using blockchain technology to enhance the traceability and security of product ownership. The model ensures seamless interaction among various stakeholders, such as manufacturers, distributors, retailers, and customers, while maintaining the authenticity of products throughout their lifecycle. Below,

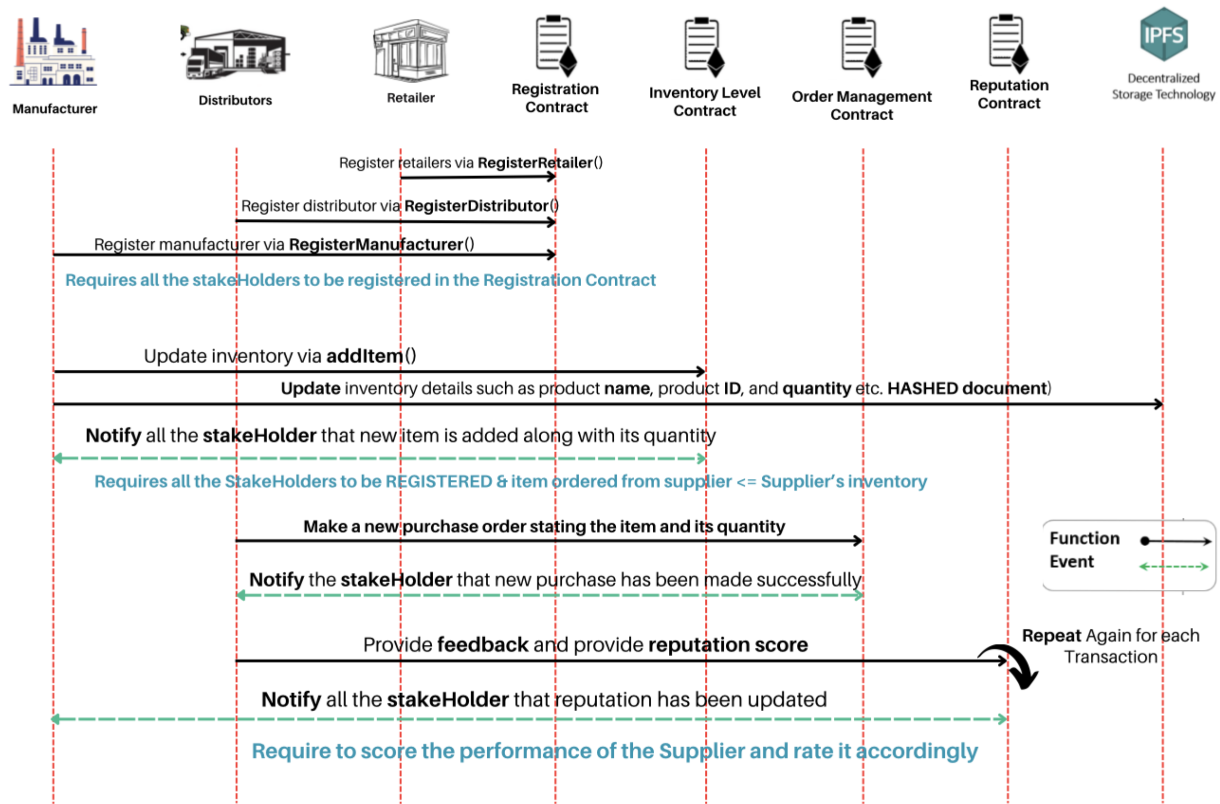

Fig. 8: This figure shows the working of the application and its functioning in the different stages[42].

we explain how the system operates based on the architecture provided in the figures.

Some of the workings are shown below :-

1. Stakeholder Registration

- The system begins with the registration of stakeholders. Each stakeholder (manufacturer, distributor, retailer, or customer) must register themselves using our decentralized application (dApp).
- Manufacturers use the *RegisterManufacturer()* function to register their accounts.
- Distributors and retailers register via *RegisterDistributor()* and *RegisterRetailer()*, respectively.
- All stakeholders must be registered in the blockchain network before participating in any transactions.

The registration ensures that only authorized entities can interact with the system, creating a secure environment for all operations.

2. Product Registration

- Manufacturers are responsible for registering the products they produce.
- When a manufacturer creates a new product, it is enrolled in the blockchain system using the *addItem()* function.
- The product is assigned a unique hash code, which acts as its immutable identifier.
- The product details, such as product name, ID, and quantity, are stored securely on the blockchain, with hashed metadata uploaded to decentralized storage (e.g., IPFS).

This ensures that every product in the supply chain is authentic and traceable from its point of origin.

3. Ownership Transfer

Once a product is registered, it is transferred through the supply chain. Ownership transfer occurs in several stages:

- From Manufacturer to Distributor: The manufacturer ships the product to a registered distributor using the *transferProduct()* function. The blockchain updates the current owner of the product to reflect this transfer.
- From Distributor to Retailer: Distributors send the product to retailers by invoking the same function. The ownership is again updated on the blockchain, ensuring accurate tracking.
- From Retailer to Customer: Customers purchase the product from retailers. The customer's wallet checks the product hash code to verify ownership before completing the transaction.
- The product ownership is finally transferred to the customer, ensuring end-to-end traceability.

This ensures that every product in the supply chain is authentic to the Owner.

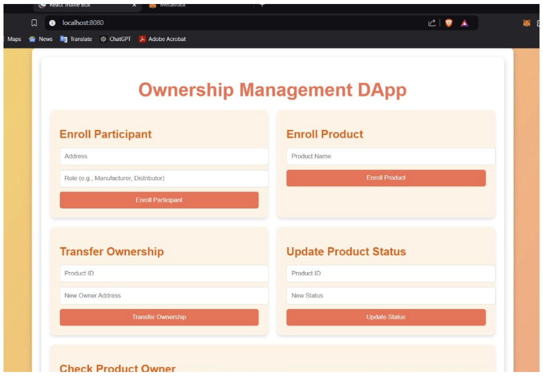

Fig. 9: The figure shows the page of my application where Product Ownership Management and tracking is taking place.

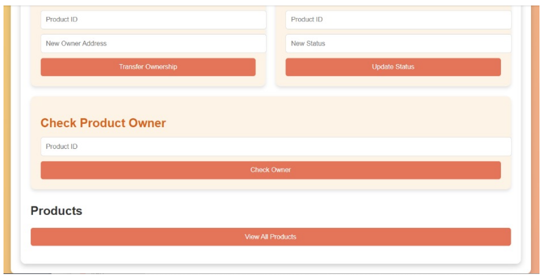

Fig. 10

4. Inventory Management

- Throughout the process, stakeholders update their inventory via the *addItem()* and *transferProduct()* functions.
- Manufacturers, distributors, and retailers maintain accurate inventory records for their respective products.
- The inventory updates are broadcast to all stakeholders, ensuring transparency and synchronization in the supply chain.
- The inventory details, such as product quantity and hashed metadata, are uploaded to IPFS, ensuring secure storage and preventing tampering.

This updates that every product in the supply chain is marked and its availability is determined.

5. Feedback and Reputation System
To ensure accountability and encourage trust, we have incorporated a reputation scoring mechanism in the system.

- After a transaction is completed, stakeholders can provide feedback on their experience.
- The reputation of the involved parties is updated using the *updateReputation()* function.
- A high reputation score reflects good practices, while a lower score alerts others in the network to potential risks.
- This feedback mechanism ensures that all stakeholders operate fairly, further safeguarding the system from counterfeit or malicious activities.

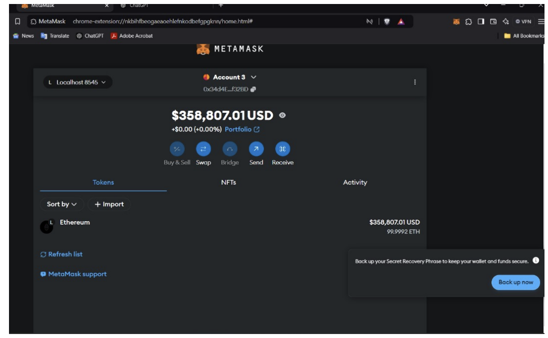

Fig. 11: The figure shows us the total Ethereum present in our Account that is required in payment of all the transactions gas fees.

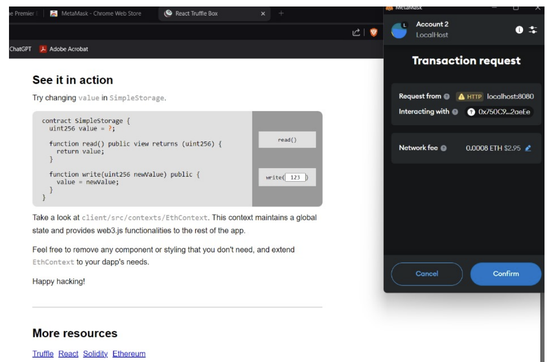

Fig. 12: The figure represents the initialization of the Blockchain Connectivity to allow transactions between stakeholders.

V. Conclusion

In this research, we have proposed and implemented a Product Ownership Management System (POMS) using blockchain technology integrated with the InterPlanetary File System (IPFS). This system addresses a critical issue in the modern supply chain: ensuring product authenticity and ownership traceability to combat counterfeiting.

Our solution leverages blockchain's decentralized, immutable, and transparent nature to provide a secure and tamper-proof record of product ownership. By integrating IPFS, we enable efficient and distributed storage of product-related metadata, ensuring scalability and data integrity. Each product is assigned a unique identifier stored on the blockchain, linked to its metadata on IPFS. This approach enhances security, as the combination of cryptographic mechanisms and distributed storage makes the system resilient against tampering and unauthorized modifications.
The system provides the following key benefits:
Counterfeit Prevention: By enabling stakeholders to verify product authenticity through blockchain records, the system effectively mitigates the risk of counterfeit goods.
Ownership Traceability: The immutable transaction history ensures complete transparency of product ownership, from manufacturer to end consumer.

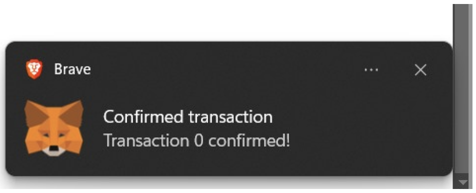

Fig. 13: This fig shows the completion of the transaction via Metamask.

Enhanced Security: Decentralized storage in IPFS, combined with blockchain's cryptographic features, ensures robust protection against data breaches and unauthorized access.
Scalability: Using IPFS reduces the burden on the blockchain for storing large files, ensuring scalability without compromising performance.
This research demonstrates the practical viability of using blockchain and IPFS for securing product ownership information. However, future work can address certain limitations, such as improving the efficiency of the blockchain consensus mechanism, enhancing user interfaces for broader adoption, and integrating IoT devices for real-time product tracking.

Overall, the Product Ownership Management System is a significant step forward in ensuring product security and trust in supply chains, presenting a sustainable solution to counterfeiting in a variety of industries.
The project is the combined with the technologies like Metamask, Ethereum Smart Contract and Wallet.

- The whole project starts with the architecture as shown in Figure.8. We designed the Smart contract regarding the architecture in the Remix-Ethereum environment. We complied the smart contract and got he functionality mentioned in the architecture.
- Fig.14 to Fig.16 describes the various functionality and attributes of the smart contract with their respective output. We also describes in Fig.14 if any hacker tries to add any product or tries to change the product then the error will be generated. Only authorized user can access the network.
- The proposed frontend is described in the Fig.9 and Fig.10 with connectivity with Metamask wallet as shown in Fig.11.
- The metamask wallet will provide the gas needed for the transaction fees. Fig.13 shows the notification regarding completion of Transaction. If wallet doesn't have enough balance then transactions will not be initiated.
- The interested candidate can check out the project on " https://github.com/ShriKant010102/BlockChain-OwnershipManagementSystem.git ".

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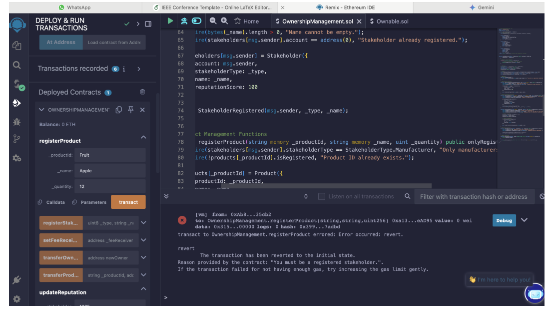

Fig. 14: This figure describes the action where an unrecognized user tried to add the product in the Network.

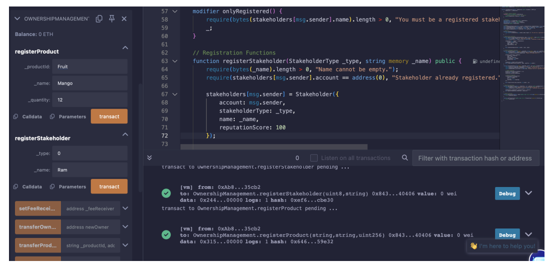

Fig. 15: This figure shows the registration process of the stakeholder and then the registered stakeholder added the product in the market.

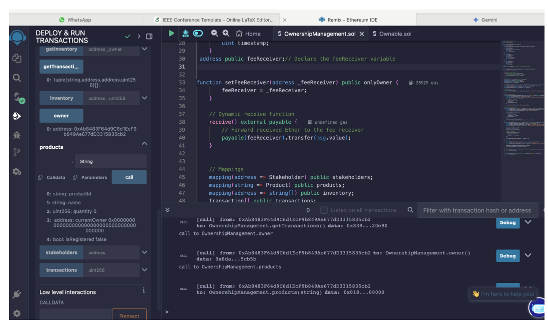

Fig. 16: Checking if any product is available in the present stakeholder.

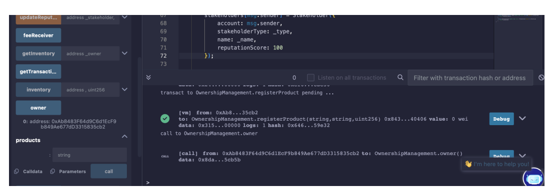

Fig. 17: This figure shows about the function where we check who is the current owner of the product

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