# Shipment Management Tracking System


1st Snehashisa Subudhiratna
*Computer Science and Engineering,MTech*
*IIIT Bhubaneswar*
Odisha, India
a124013@iiit-bh.ac.in

2nd Srichandan Sobhanayak
*Computer Science and Engineering*
*IIIT Bhubaneswar*
Odisha, India
srichandan@iiit-bh.ac.in

3rd Anita Sahoo
*Computer Science and Engineering*
*IIIT Bhubaneswar*
Odisha, India
C122001@iiit-bh.ac.in



***Abstract*—This study examines the issues associated with conventional shipment monitoring systems, such as opacity, ineffectiveness, and susceptibility to deception. We introduce a shipment tracking solution based on blockchain technology that utilizes decentralized ledger systems, intelligent contracts, and Internet of Things (IoT) integration to deliver a robust, visible, and streamlined approach.. Key features include real-time tracking, automated compliance checks, and immutable record-keeping. The system's architecture comprises IoT, blockchain, data storage, and application layers. Anticipated benefits include enhanced visibility across the supply chain, reduced operational costs, improved security, and increased trust among stakeholders. This innovation possesses the potential to significantly transform global shipping logistics and optimize international trade processes.**



***Index Terms*—component, formatting, style, styling, insert**


## I. Introduction

In today's globalized economy, efficient and reliable shipment tracking is crucial for supply chain management. However, traditional shipment tracking systems face significant challenges that hinder their effectiveness and reliability. Challenges in Traditional Shipment Tracking: Lack of Transparency: Information silos between different stakeholders often lead to incomplete or inconsistent data about shipment status and location. Inefficiency: Manual processes and paperwork cause delays, errors, and increased operational costs. Susceptibility to Fraud: Centralized systems are vulnerable to data tampering and fraudulent activities. Insufficient Real-time Visibility: Conventional systems often struggle to provide accurate, up-to-the-minute information on shipment progress. The innovative approach of blockchain technology, with its decentralized and distributed ledger system, offers a potential solution to overcome these shortcomings. [1], blockchain provides: Immutability: Once recorded, data cannot be altered or deleted, ensuring a trustworthy audit trail. Decentralization: No single entity controls the entire system, reducing the risk of manipulation or a single point of failure. Transparency:Identical information is accessible to all approved parties, promoting confidence and improving teamwork. These unique characteristics highlight the importance of adopting a shipment tracking system based on blockchain technology, which directly address the limitations of traditional systems [2] [3].The adoption of blockchain technology enables the development of a shipment tracking ecosystem that is more transparent, efficient, and secure. Objectives of this paper: To design a comprehensive architecture for a blockchain-based shipment tracking system [4] [5]. The integration of IoT devices with blockchain facilitates real-time data collection and verification, enhancing transparency, security, and efficiency. This technological synergy is especially impactful in applications such as financial transactions.To explore the implementation of smart contracts for automating shipping processes and ensuring compliance. Blockchain also significantly improves security by preventing tampering and fraud, protecting valuable supply chain information. Cost reduction and increased efficiency are achieved through automation via smart contracts, streamlining inventory management and order fulfillment while reducing paperwork and intermediaries. The technology fosters better collaboration among partners by providing a unified source of information, reducing confusion and improving communication. Additionally, blockchain aids in maintaining regulatory compliance and managing risks through automated processes and enhanced product traceability [6]. Real-time tracking capabilities enable quicker identification and resolution of supply chain issues, leading to proactive problem-solving and improved overall supply chain performance [7] [8]. To analyze the potential benefits and challenges of adopting blockchain technology in shipment tracking. Scope: This paper will focus on the conceptual design and technical architecture of a blockchain-based shipment tracking system. While we will discuss potential real-world applications, the implementation details may vary based on specific industry requirements and technological constraints [9]. By addressing these objectives, we aim to demonstrate how blockchain technology can revolutionize shipment tracking, providing a more transparent, efficient, and secure solution for global supply chain management.

- Proposing a new five-layered blockchain-based IoT-enabled logistics management framework that utilizes smart contracts.
- Designing and describing a sequence diagram that illustrates the secure communication between logistics stakeholders through the blockchain smart contract.
- Integrating IoT sensors for data capture within the logistics management system, enhancing real-time tracking and monitoring capabilities.
- Addressing security and privacy concerns in logistics operations by implementing encryption mechanisms for

sensitive customer and product information .

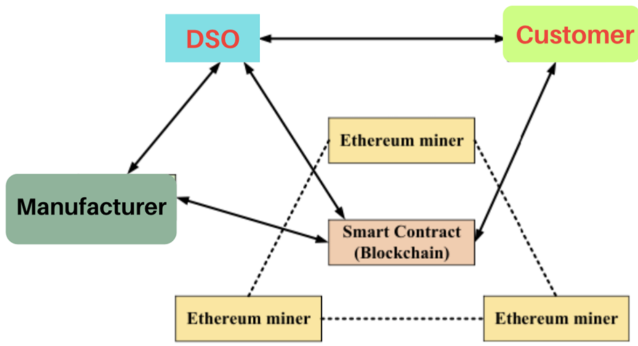


Fig. 1. Working Model of supply management in blockchain

The Fig.1 depicts a schematic representation of a system comprising a Customer, Manufacturer, and Ethereum miners. It illustrates the interrelationships among these entities and the Smart Contract within the Blockchain framework. The diagram incorporates parallel lines and rectangles to delineate connections and processes associated with Ethereum mining. The overall design emphasizes textual elements in a structured format.

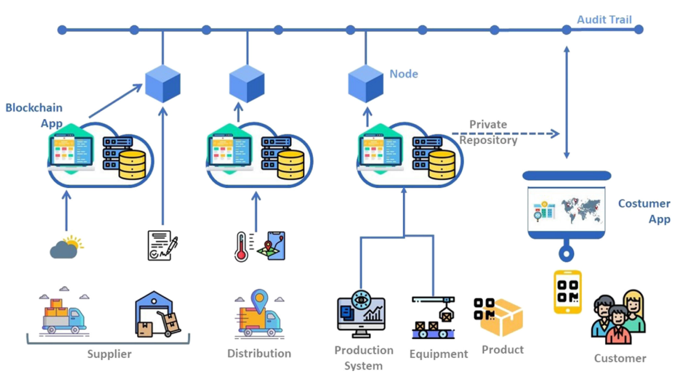


Fig. 2. Basic Block Diagram for Shipment Tracking System

The above Fig.2 explain about the system employs a blockchain application to document and monitor each phase of the supply chain, ensuring transparency and traceability. Data from each stage (supplier information, meteorological conditions affecting transport, production data, location, etc.) is uploaded to nodes in the blockchain network. A private repository stores the comprehensive audit trail generated by the blockchain, accessible via a client application. The client application facilitates product tracking and verification of its progression through the supply chain. The entire system utilizes an audit trail for comprehensive traceability and accountability.

## II. Literature survey/related work

Blockchain technology has emerged as a transformative force in logistics and supply chain management, offering unprecedented levels of transparency, security, and efficiency. This literature review critically examines the integration of blockchain in these domains, with a focus on shipment tracking systems.Supply Chain Management and Logistics with Blockchain According to recent research, supply chain processes could be completely transformed by blockchain technology. Kshetri (2018) highlights blockchain's ability to enhance traceability and reduce fraud in global supply chains [10] [11]. Similarly, Saberi et al. (2019) emphasize the technology's role in improving transparency and trust among supply chain partners. [12] [4] In the context of shipment tracking, blockchain offers real-time visibility and immutable record-keeping. Tian (2017) proposes a blockchain-based system for food traceability [13], showcasing improved efficiency and reduced information asymmetry. These findings underscore blockchain's capacity to address longstanding challenges in logistics, such as lack of end-to-end visibility and data silos [14]Evaluation of Existing Blockchain-Based Shipment Tracking Systems [15]Several blockchain-based shipment tracking systems have been developed and implemented. TradeLens, a collaboration between IBM and Maersk, utilizes the Hyperledger Fabric platform to facilitate information sharing among stakeholders in the shipping industry. Another notable example is CargoX, which leverages the Ethereum blockchain for digital bill of lading processes. [16] These systems demonstrate the feasibility of blockchain in real-world logistics applications. However, they also reveal limitations. For instance, TradeLens faced challenges in achieving widespread industry adoption due to concerns about data ownership and competition.

Challenges and LimitationsDespite the promising potential, blockchain-based shipment tracking systems face several challenges. Scalability remains a significant concern, with many blockchain networks struggling to handle the high transaction volumes typical in global supply chains [17]. Interoperability issues also persist, as different blockchain platforms often lack standardized protocols for data exchange.

Furthermore, the integration of blockchain with existing legacy systems poses technical and organizational challenges. Dobrovnik et al. (2018) note that the high costs of implementation and the need for industry-wide collaboration are significant barriers to adoption .Research Gaps and Future Directions: This review reveals several research gaps in the current literature. First, Comprehensive research on the long-term financial effects of blockchain adoption in logistics is lacking. Second, research on user-friendly interfaces for blockchain-based tracking systems is limited, potentially hindering user adoption [2].

Existing blockchain solutions address several key security threats in logistics through various mechanisms. The immutable and tamper-proof nature of blockchain records ensures data integrity and provides an auditable trail of all transactions. Decentralization eliminates single points of failure and reduces reliance on intermediaries, enhancing overall security [18]. Cryptographic techniques are employed for authentication and access control, allowing only authorized parties to modify data. Real-time visibility and traceability enabled by blockchain help in detecting counterfeit products and financial irregularities. [19] Integration with IoT devices allows for continuous monitoring of shipment conditions, triggering smart contracts if violations occur. Encryption protects sensitive information, while automated compliance checks through smart contracts ensure regulatory requirements are met. The transparent and shared ledger facilitates secure information exchange between stakeholders. However, challenges remain, including potential vulnerabilities to phishing, routing, Sybil, and 51% attacks [20].

Privacy concerns in public blockchains are addressed through the use of private or permissioned blockchains and hashing technology. While blockchain significantly enhances security in logistics, it is not entirely immune to cyberattacks, and organizations must remain vigilant and implement comprehensive security strategies that combine traditional security controls with blockchain-specific measures. By offering end-to-end visibility, data integrity, and security across the supply chain, the combination of blockchain with IoT greatly improves logistical reliability. Blockchain generates an unchangeable record of this data, guaranteeing transparency and traceability, while IoT devices provide real-time data on product location, condition, and movement. The cryptographic nature of blockchain secures data collected from IoT devices, preventing tampering and increasing trust. Smart contracts automate processes like payments and compliance checks based on predefined conditions triggered by IoT sensors [21] [22]. This integration improves quality control by monitoring environmental conditions during transport, enhances authentication and fraud prevention, enables efficient recall management, and facilitates real-time decision making. Increased accountability is achieved as all actions are recorded immutably, while streamlined documentation reduces paperwork and potential errors [23]. The combination also optimizes asset utilization through real-time data analysis [24]. By addressing key challenges in traditional logistics systems such as lack of visibility, data silos, and manual processes, the blockchain-IoT integration creates a more robust [25], efficient, and dependable supply chain ecosystem [26].

Furthermore, not enough research has been done on how blockchain may be integrated with other cutting-edge technologies, such as the Internet of Things and artificial intelligence, to improve supply chain visibility. Future research should address these gaps to advance the field of blockchain-based shipment tracking [27].In conclusion, while blockchain shows great promise in revolutionizing shipment tracking and supply chain management [28], significant challenges remain. Addressing these challenges and filling the identified research gaps will be crucial for developing more effective and widely adopted blockchain-based solutions in logistics.

The Fig.3 depicts a supply chain management system that combines the Internet of Things (IoT) and blockchain technology to produce a decentralized, transparent, and efficient process. This multi-layered architecture comprises a user interface, application management, blockchain infrastructure, IoT integration, and physical components. The system leverages

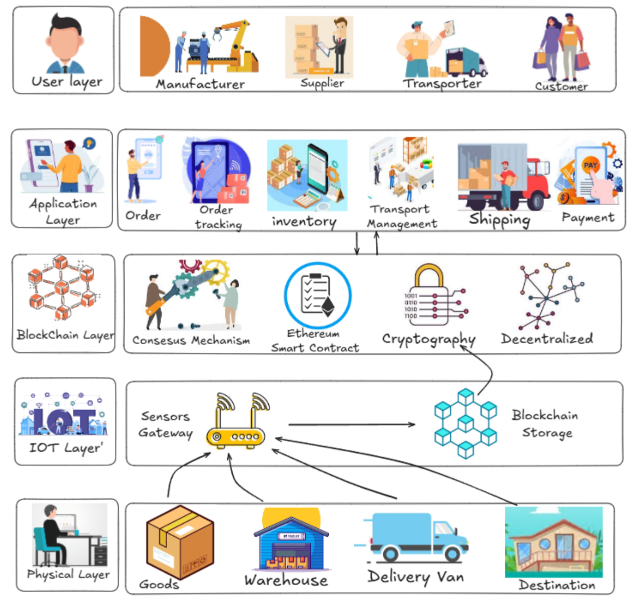


Fig. 3. Blockchain-based framework for Shipment Tracking management system

Ethereum smart contracts for process automation and secure transaction execution, while a consensus mechanism ensures data integrity across the distributed network. IoT sensors and gateways provide real-time monitoring of goods throughout the supply chain, from warehouse to final delivery. By generating an unchangeable record of all transactions and movements, this blockchain-IoT collaboration improves efficiency, security, and traceability. Because the system is decentralized, there are fewer single points of failure and less likelihood of data alteration, which increases participant trust. By automating key processes and providing real-time visibility, this integrated approach optimizes supply chain operations, reduces costs, and improves overall performance in the increasingly complex global trade environment.

## III. Preliminaries

This section establishes the foundational concepts and terminologies essential for understanding our blockchain-based shipment tracking system. Key Terms and Concepts

### A. Blockchain technology

Blockchain technology is a distributed, decentralized ledger technology that keeps track of transactions on several different computers. A chain of blocks is created by cryptographically connecting each record, or block, to the one before it. This structure establishes an unchangeable transaction history and guarantees data integrity.

### B. Smart Contracts

Smart contracts are self-executing agreements that have their terms encoded directly into the code. They facilitate, confirm, or enforce the negotiation or fulfillment of a contract by automatically executing when certain circumstances are met. [29].

### C. Distributed Ledger Technology (DLT)

DLT is the broader category of technologies that includes blockchain. It refers to a decentralized database managed by multiple participants, with no central authority. DLT allows for transparent, verifiable, and permanent data recording.

### D. Hash Function

Cryptographic methods known as hash functions transform any size of input data into a fixed-size output, or hash. Since they are one-way functions, reversing the process is not computationally viable. In blockchain systems, hash functions are essential for guaranteeing data integrity. Blockchain-Integrated Workflow for a Shipment Tracking System .

### E. Wallet

In the context of cryptocurrencies, wallets are hardware or software instruments for managing, storing, and interacting with digital assets. They fall into two primary categories:

- Hot Wallets: Internet-connected software wallets used for frequent transactions and active trading.
- Cold Wallets: Offline storage devices, such as hardware wallets or paper wallets, offering enhanced security for long-term storage.

### F. Gas

Gas is a crucial concept in Ethereum , serving as a mechanism to prevent spam and allocate network resources efficiently. It consists of two components:

- Gas Limit: The maximum amount of computational work a user is willing to pay for a transaction56.
- Gas Price: The cost per unit of gas, typically denominated in gwei56.The total gas fee is calculated as: Gas Used * (Base Fee + Priority Fee), where the base fee is set by the network, and the priority fee is an optional tip to incentivize faster processing

### G. Traditional Workflow

Shipment creation and documentation Pickup and initial scanning Transport and intermittent scanning at checkpoints Delivery and final scanning Confirmation and closure .

### H. Blockchain-Integrated Workflow

Shipment creation: Data is recorded on the blockchain, establishing an immutable entry. Smart contract initiation: Terms and conditions are encoded into a smart contract. IoT integration: Sensors affixed to the shipment continuously transmit data to the blockchain. Real-time updates: Each checkpoint scan or sensor reading initiates a blockchain transaction. Automated actions: Smart contracts execute predefined actions based on recorded data (e.g., release payments, trigger alerts). Delivery confirmation: Final status update recorded on the blockchain.Consensus Mechanisms: Consensus mechanisms are protocols that ensure all nodes in a blockchain network agree on the validity of transactions. For our shipment tracking system, we consider two primary mechanisms:

### I. Consensus

Consensus in blockchain refers to the process by which nodes (participants) in a decentralized network reach agreement on the validity and order of transactions in the ledger. In the absence of a central authority, Consensus techniques require agreement from dispersed participants, ensuring the blockchain's security, consistency, and integrity.

- Proof of Work (PoW): Miners compete to solve complex computational puzzles in order to validate transactions and add new blocks to the blockchain.
- Proof of Stake (PoS): Validators are chosen based on the amount of stake (ownership) they hold, and they are responsible for confirming transactions.
- Delegated Proof of Stake (DPoS): In this system, stakeholders elect a small group of trusted delegates to validate transactions on their behalf.
- Practical Byzantine Fault Tolerance (PBFT): Nodes achieve consensus through communication, ensuring resilience against faulty or malicious nodes.
  Consensus mechanisms are fundamental to maintaining trust and mitigating fraudulent activities in blockchain systems.

### J. Proof of Work (PoW)

Operational principle: Nodes compete to solve complex mathematical puzzles. The first to solve it is granted the right to add the next block to the chain. Advantages: High security, well-established. Disadvantages: Energy-intensive, potentially slower transaction speeds.

### K. Proof of Stake (PoS)

In our proposed shipment tracking system, we recommend using a Proof of Stake (PoS) consensus mechanism, where validators are chosen based on the amount of cryptocurrency they hold and are willing to stake as collateral. PoS offers advantages such as energy efficiency and potentially faster transaction speeds compared to Proof of Work (PoW), and it can handle a higher number of transactions per second, which is crucial for real-time tracking of multiple shipments. Additionally, PoS lowers entry barriers, enabling more stakeholders to participate in the network and promoting decentralization. By integrating blockchain with traditional tracking methods, our system ensures data integrity, automates processes via smart contracts, and provides a secure, transparent, and efficient solution for the logistics industry. This integration fosters trust and real-time tracking for all stakeholders involved in the shipping process.

The Fig.4 illustrates the fundamental components and processes of distributed ledger technology. It depicts the blockchain as a series of interconnected blocks, each containing a set of validated transactions. These blocks form a chronological, immutable chain stored in a distributed ledger across multiple nodes. The system employs consensus mechanisms, such as proof-of-work, to confirm and add additional blocks, guaranteeing the confidentiality and integrity of data. Miners, who perform the computational work required for

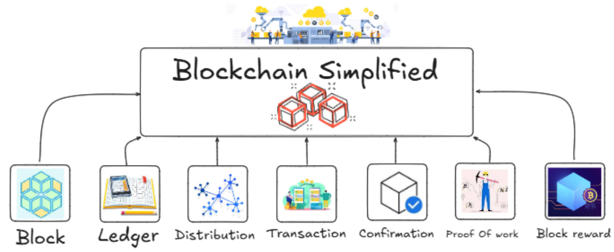


Fig. 4. working model of Blockchain

block validation, receive block rewards as incentives. This decentralized architecture enhances resilience against manipulation and single points of failure. The diagram effectively conveys the core concepts of blockchain technology, including transaction processing, block formation, consensus achievement, and the distributed nature of the ledger, while abstracting the underlying technical complexities.

## IV. Proposed Model

This Fig.5 illustrates an integrated IoT-blockchain ecosystem that exemplifies the convergence of multiple technological strata for efficient data management and processing. The IoT and Edge Layer comprises RFID tags, GPS trackers, and environmental sensors interfacing with an Arduino microcontroller, which transmits data to the Data Storage Layer utilizing IPFS (InterPlanetary File System) for decentralized storage. The Blockchain Layer implements Ethereum's smart contract functionality through distributed nodes, while the Application Layer facilitates user interaction through a unified API interface, thereby establishing a robust and secure end-to-end system for data collection, validation, and accessibility across multiple platforms.

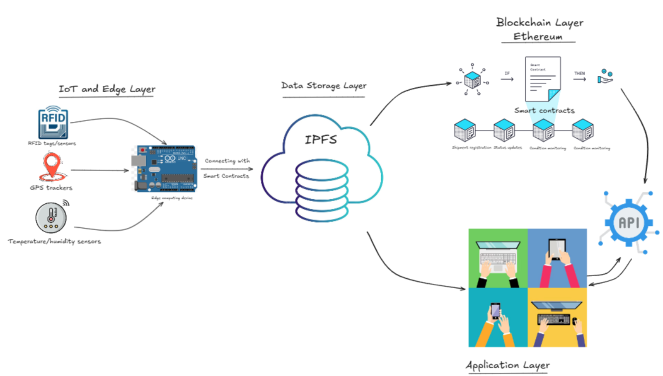


Fig. 5. Architecture of Shipment Tracking System

1) **System Components**

*IoT and Edge Layer*

- **Sensors:**Temperature/humidity sensors, GPS trackers, and RFID tags all gather data in real time on a variety of characteristics.
- **Arduino Board:** serves as the edge computing device that collects, processes, and filters data from all sensors in order to store and process it more effectively.

*Data Storage Layer*

- **IPFS (InterPlanetary File System):** A decentralized storage solution where data is stored in a distributed manner. It ensures data availability, persistence, and fault tolerance by assigning unique content identifiers to each piece of data.

*Blockchain Layer*

- **Ethereum Blockchain:** Smart contracts on Ethereum process and validate data. Blockchain ensures data immutability and transparency, and multiple nodes work to maintain consensus and security.
- **Smart Contracts:** Automatically execute predefined business logic based on incoming data, such as triggering actions or notifications when specific conditions are met.

*Application Layer*

- User interfaces (mobile, desktop) allow for easy interaction with the system, while APIs integrate external services for enhanced functionality.
- **Data Visualization and Monitoring:** The system provides real-time access to processed data, allowing users to track IoT devices and sensor information.

2) **process Flow**

*Data Collection*

- IoT sensors collect real-time data from various environments (e.g., location, temperature, humidity).
- Data is processed by the Arduino board, which aggregates and filters the information for transmission.

*Data Storage*

- Processed data is sent to IPFS for decentralized storage. IPFS ensures the data is uniquely identified, accessible, and persists across the distributed network.

*Blockchain Integration*

- Smart contracts on the Ethereum blockchain receive the data from IPFS and validate it. These contracts also automate processes like triggering actions when certain conditions are met, such as updating logs or initiating alerts.
- Consensus is achieved across multiple blockchain nodes, ensuring data integrity.

*User Access*

- Through desktop and mobile applications, the system offers a user interface that enables users to monitor and communicate with Internet of Things devices.
- External system integration is made possible by APIs, and only authorized users are able to interact with data and manage the system thanks to safe, authenticated access.

KEY BENEFITS

- **Security:** Blockchain ensures the integrity of data, preventing tampering or unauthorized changes.
- **Decentralization:** IPFS and Ethereum's distributed network provide fault tolerance and enhanced availability.
- **Automation:** Smart contracts automate processes based on real-time IoT data.
- **Transparency and Immutability:** Blockchain guarantees transparent and unchangeable records of all data transactions and system actions.

## V. TECHNOLOGY REQUIREMENTS

Developing a comprehensive supply chain management system with IoT connectivity using blockchain technology will require a carefully chosen collection of platforms, tools, and technologies. Here is a thorough explanation:

### A. Blockchain Platform

Hyperledger Fabric will be utilized as the blockchain platform. This selection is substantiated by several factors:

- Enterprise-grade: Hyperledger Fabric is engineered for business use cases, providing the requisite privacy and permissioned access for supply chain management
- Modular architecture: It facilitates plug-and-play components, enabling high customizability to specific requirements.
- Smart contract support: Fabric accommodates "chaincode" (smart contracts) written in general-purpose languages such as Go, Java, and JavaScript
- Scalability: Fabric's architecture enables superior scalability compared to public blockchains like Ethereum.

### B. Development Tools and Languages

- Solidity: It will serve as the primary language for authoring chaincode (smart contracts) on Hyperledger Fabric. Solidity is efficient, concurrent, and well-supported by the Fabric community.
- Remix :Remix is an Ethereum-based framework and development environment for building decentralized applications (dApps). Remix IDE, a web-based tool, allows developers to write, test, and deploy smart contracts on the Ethereum blockchain using Solidity. It offers features like smart contract development, testing, debugging, and deployment to Ethereum networks, making it a powerful tool for Ethereum developers to create and interact with blockchain-based applications.
- Node.js: For developing the backend services and APIs that interface with the blockchain network JavaScript/TypeScript: For frontend development, facilitating the creation of a user-friendly interface for supply chain participants
- Visual Studio Code: As the primary Integrated Development Environment (IDE), with extensions for blockchain and IoT development
- Docker: For containerization, essential for deploying Hyperledger Fabric components and ensuring consistent environments across development and production Hardware Requirements.

### C. Hardware Requirements

- IoT Devices: ESP32-based devices will be employed for shipment tracking. ESP32 offers integrated Wi-Fi and Bluetooth capabilities, rendering it suitable for IoT applications.
- RFID Tags and Readers: For automated inventory tracking and management. [30] [31]
- GPS Modules: To be connected to Internet of Things devices in order to track shipments' locations in real time.
- Environmental Sensors: Temperature and humidity sensors to monitor conditions for sensitive goods.

### D. Software and Infrastructure

- Cloud Infrastructure: Amazon Web Services (AWS) will be utilized for its comprehensive suite of services:EC2 instances for hosting blockchain nodes, S3 for data storage, IoT Core for managing IoT devices, Lambda for serverless computing task .
- Kubernetes: For orchestrating and managing containerized applications, ensuring high availability and scalability .
- MongoDB: As a NoSQL database for storing off-chain data and enhancing query performance .
- Redis: For caching and improving system responsiveness.

### E. APIs and Middleware

- Hyperledger Fabric SDK: The official Fabric SDK for Node.js will be utilized to interact with the blockchain network .
- RESTful APIs: These will be developed using Express.js to expose blockchain and IoT data to frontend applications.
- GraphQL: This will be employed for more efficient and flexible data querying, particularly beneficial for complex supply chain data structures.

- MQTT: This will serve as a lightweight messaging protocol for IoT device communication.
- Integration Middleware: An Enterprise Service Bus (ESB) will be implemented using Apache Camel to facilitate communication between different components of the system, including legacy systems that may be utilized by supply chain partners.

### *F. Ethereum*

Ethereum is an open-source, decentralized blockchain platform that facilitates the development and operation of decentralized apps (DApps) and smart contracts. By adding a Turing-complete programming language, it expands the potential of blockchain technology beyond simple money transfer and makes it possible to carry out intricate calculations on its network.

- The native coin of the Ethereum network, Ether (ETH), is used as a store of value and for transaction fees.
- Smart contracts are self-executing agreements that automatically enforce and carry out certain conditions since their terms are explicitly put into code.
- The Ethereum Virtual Machine (EVM) provides a runtime environment for Ethereum network smart contracts that guarantees uniform execution on all nodes.
- Gas: A measure of computational effort required to execute operations on the Ethereum network, priced in small fractions of ether called gwei.

### *G. Hardhat*

The system utilizes a blockchain application to document and monitor each phase of the supply chain, ensuring transparency and traceability. Data from each stage (supplier information, meteorological conditions affecting transport, production data, location, etc.) is uploaded to nodes in the blockchain network. A private repository stores the comprehensive audit trail generated by the blockchain, accessible via a client application. The client application facilitates product tracking and verification of its progression through the supply chain. The entire system employs an audit trail for comprehensive traceability and accountability.

### *H. Meta Mask*

MetaMask is a cryptocurrency wallet that allows users to interact with the Ethereum blockchain and decentralized applications (dapps). It's available as a browser extension or mobile app . Features: MetaMask offers a secure login, key vault, token wallet, and token exchange. It also generates passwords and keys on your device.

### *I. WEB3*

Web3 is a decentralized internet that gives consumers more control over their transactions, digital identities, and data by utilizing blockchain technology. Web3 facilitates peer-to-peer interactions via decentralized apps (dApps), cryptocurrencies, and smart contracts, allowing for increased transparency, security, and digital ownership in contrast to Web2, which is dominated by centralized platforms.

### *J. IPFS*

The InterPlanetary File System (IPFS) is a decentralized peer-to-peer file storage system that uses content addressing to store and share data, allowing it to handle massive volumes of data without the storage constraints of blockchain. IPFS complements blockchain by providing decentralized data storage, while blockchain supports file traceability metadata and ensures immutability. The two technologies work together seamlessly, as IPFS uses cryptographic hashes to identify files, which can be stored on the blockchain for easy access and verification. This combination enables efficient data storage, supports file traceability, ensures data integrity by protecting against modifications, and allows for content archiving, offering a robust solution for decentralized applications.

### *K. React*

React is a widely utilized open-source JavaScript library employed for constructing user interfaces, particularly for single-page applications. It enables developers to create reusable UI components that efficiently update and render when data undergoes changes. Developed and maintained by Facebook, React employs a virtual DOM (Document Object Model) to optimize rendering performance, thereby enhancing the speed and responsiveness of web applications. React is frequently utilized in conjunction with other libraries or frameworks to manage state and routing, facilitating the development of dynamic and interactive web applications.

### *L. Development and Testing Tool*

- Hyperledger Caliper: This will be employed for benchmarking and performance testing of the blockchain network.
- Jest: This will be utilized for unit and integration testing of the Node.js applications.
- Postman: This will be used for API testing and documentation.
- ELK Stack(Elasticsearch, Logstash, Kibana): This will be employed for log management and system monitoring.Through the utilization of these tools, platforms, and technologies. The combination of Hyperledger Fabric's enterprise features, advanced development tools, and carefully selected hardware and software components will enable the fulfillment of the complex requirements of modern supply chain operations.

## VI. Proof of Implementation

The ShipmentTrackingSystem smart contract, Fig.6 and Fig.7 is a decentralized application designed for secure and transparent shipment tracking on the Ethereum blockchain. It facilitates the management of shipments through predefined statuses (Created, In Transit, and Delivered), with each shipment uniquely identified by a tracking number. Essential information, including sender, recipient, timestamp, current location, and status, is stored immutably on the blockchain. The sender exclusively possesses the authority to update shipment status and location, ensuring access control and data integrity. The contract emits events for shipment creation and tracking updates, enabling real-time notifications to stakeholders. A public function provides access to shipment details, promoting transparency and accountability.

```solidity
pragma solidity ^0.8.0;

contract ShipmentTrackingSystem {
    enum ShipmentStatus { Created, InTransit, Delivered }

    struct Shipment {
        address sender;
        address recipient;
        uint256 timestamp;
        ShipmentStatus status;
        string trackingNumber;
        string currentLocation;
    }

    mapping(string => Shipment) public shipments;
    uint256 public shipmentCount;

    event ShipmentCreated(string trackingNumber, address sender, address recipient);
    event ShipmentTracked(string trackingNumber, ShipmentStatus status, string location);

    function createShipment(address _recipient, string memory _trackingNumber) public {
        require(shipments[_trackingNumber].sender == address(0), "Shipment already exists");

        shipments[_trackingNumber] = Shipment({
            sender: msg.sender,
            recipient: _recipient,
            timestamp: block.timestamp,
            status: ShipmentStatus.Created,
            trackingNumber: _trackingNumber,
            currentLocation: "Origin"
        });

        shipmentCount++;

        emit ShipmentCreated(_trackingNumber, msg.sender, _recipient);
    }
```

Fig. 6. Smart Contract

```solidity

    function trackShipment(string memory _trackingNumber, ShipmentStatus _status, string memory _location) public {
        require(shipments[_trackingNumber].sender != address(0), "Shipment does not exist");
        require(msg.sender == shipments[_trackingNumber].sender, "Only sender can track shipment");

        shipments[_trackingNumber].status = _status;
        shipments[_trackingNumber].currentLocation = _location;

        emit ShipmentTracked(_trackingNumber, _status, _location);
    }

    function getShipmentInfo(string memory _trackingNumber) public view returns (
        address sender,
        address recipient,
        uint256 timestamp,
        ShipmentStatus status,
        string memory currentLocation
    ) {
        Shipment memory shipment = shipments[_trackingNumber];
        require(shipment.sender != address(0), "Shipment does not exist");

        return (
            shipment.sender,
            shipment.recipient,
            shipment.timestamp,
            shipment.status,
            shipment.currentLocation
        );
    }
}
```

Fig. 7. Smart Contract

In the above Fig. 8, the frontend represents the user interface of the shipment tracking system. It allows users to interact seamlessly with the blockchain by creating

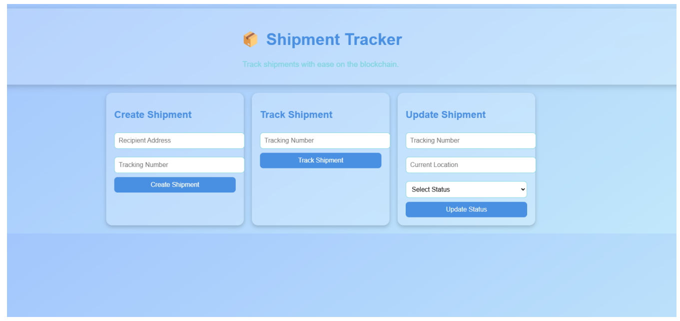


Fig. 8. Frontend Part of shipment Tracking system

shipments, updating statuses, and viewing shipment details in a user-friendly and intuitive manner.

In the Fig.9 , MetaMask serves as the bridge between users and the Ethereum blockchain, enabling secure interactions with the shipment tracking system. It allows users to manage their accounts, sign transactions, and connect to the decentralized application seamlessly.

## VII. Conclusion

In conclusion, this research presents a novel blockchain-based Internet of Things (IoT)-enabled framework for logistics management, addressing critical challenges in the industry. The proposed five-layered architecture, A reliable way to improve supply chain operations' security, transparency, and efficiency is to integrate smart contracts and Internet of Things sensors. By leveraging blockchain technology, the framework ensures immutable record-keeping and facilitates secure communication among stakeholders. Throughout the logistics process, visibility is greatly increased by the integration of IoT devices, which allows for real-time tracking and monitoring. Furthermore, the implementation of encryption mechanisms safeguards sensitive customer and product information, addressing privacy concerns inherent in traditional systems. This innovative approach not only streamlines logistics operations but also establishes a foundation for trust and accountability among participants. As the logistics sector continues to evolve, By opening the door for future advancements in the sector, this framework marks a substantial step towards a supply chain management future that is safer, more transparent, and more effective.

## References

[1] R. P. Sarode, M. Poudel, S. Shrestha, and S. Bhalla, "Blockchain for committing peer-to-peer transactions using distributed ledger technologies," *International Journal of Computational Science and Engineering*, vol. 24, no. 3, pp. 215–227, 2021.

[2] O. Alkhoori, A. Hassan, O. Almansoori, M. Debe, K. Salah, R. Jayaraman, J. Arshad, and M. H. U. Rehman, "Design and implementation of cryptocargo: A blockchain-powered smart shipping container for vaccine distribution," *IEEE Access*, vol. 9, pp. 53 786–53 803, 2021.

[3] L. W. Cong and Z. He, "Blockchain disruption and smart contracts," *The Review of Financial Studies*, vol. 32, no. 5, pp. 1754–1797, 2019.

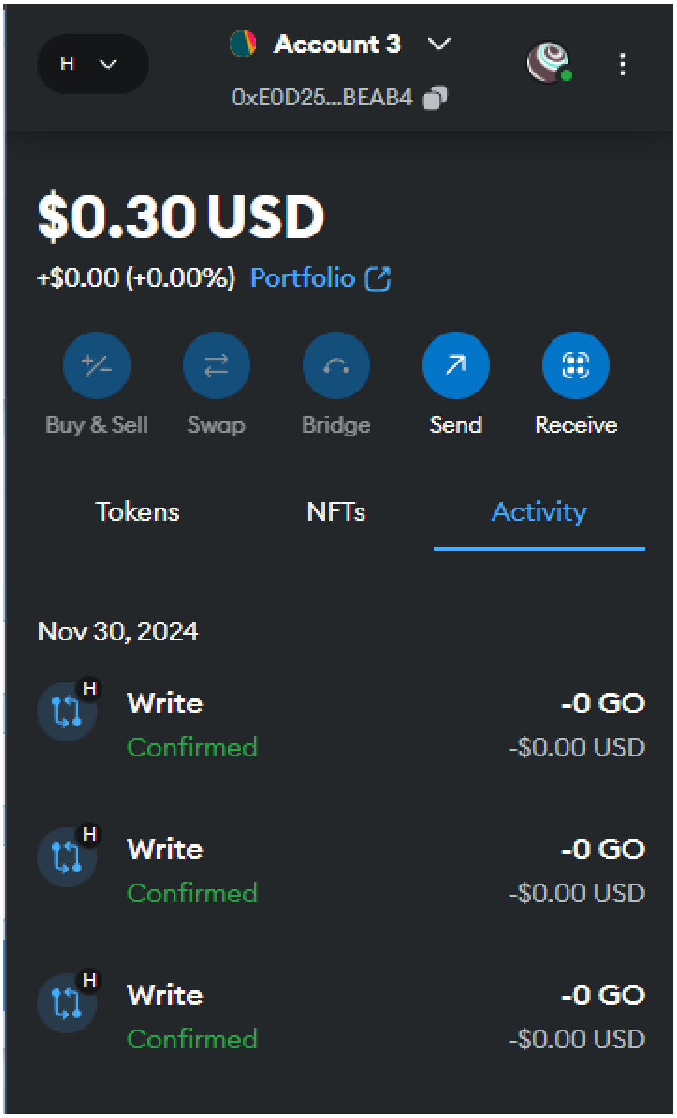


Fig. 9. Meta Mask

[4] T. Alladi, V. Chamola, B. Sikdar, and K.-K. R. Choo, "Consumer iot: Security vulnerability case studies and solutions," *IEEE Consumer Electronics Magazine*, vol. 9, no. 2, pp. 17–25, 2020.

[5] N. Gajendran, "Blockchain-based secure framework for elearning during covid-19," *Indian journal of science and technology*, vol. 13, no. 12, pp. 1328–1341, 2020.

[6] C. Patel, D. Shah, and A. Patel, "Automatic number plate recognition system (anpr): A survey," *International Journal of Computer Applications*, vol. 69, no. 9, 2013.

[7] M. G. Speranza, "Trends in transportation and logistics," *European journal of operational research*, vol. 264, no. 3, pp. 830–836, 2018.

[8] A. Panarello, N. Tapas, G. Merlino, F. Longo, and A. Puliafito, "Blockchain and iot integration: A systematic survey," *Sensors*, vol. 18, no. 8, p. 2575, 2018.

[9] M. Conoscenti, A. Vetro, and J. C. De Martin, "Blockchain for the internet of things: A systematic literature review," in *2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA)*. IEEE, 2016, pp. 1–6.

[10] N. Kshetri, "Blockchain and sustainable supply chain management in developing countries," *International Journal of Information Management*, vol. 60, p. 102376, 2021.

[11] M. Alamri, N. Jhanjhi, and M. Humayun, "Blockchain for internet of things (iot) research issues challenges & future directions: A review," *Int. J. Comput. Sci. Netw. Secur*, vol. 19, no. 1, pp. 244–258, 2019.

[12] P. B. Beserra, "Blockchain technology to improve supply chain management-a systematic literature review," Master's thesis, Universidade do Algarve (Portugal), 2020.

[13] F. Tian, "A supply chain traceability system for food safety based on haccp, blockchain & internet of things," in *2017 International conference on service systems and service management*. IEEE, 2017, pp. 1–6.

[14] N. Kshetri, "Blockchain's role in enhancing quality and safety and promoting sustainability in the food and beverage industry," *Sustainability*, vol. 15, no. 23, p. 16223, 2023.

[15] M. G. Magangi, "Effectiveness of anti-female genital cutting interventions on the psychosocial wellbeing of the girl child in marani sub-county, kisii county, kenya." Ph.D. dissertation, KISII UNIVERSITY, 2023.

[16] B. T. Teweldebrhan, P. Maghelal, and A. Galadari, "Impact of additive manufacturing on maritime transportation: a review," *Journal of International Logistics and Trade*, vol. 20, no. 4, pp. 190–209, 2022.

[17] B. Müßigmann, H. von der Gracht, and E. Hartmann, "Blockchain technology in logistics and supply chain management—a bibliometric literature review from 2016 to january 2020," *IEEE transactions on engineering management*, vol. 67, no. 4, pp. 988–1007, 2020.

[18] A. Tapscott and D. Tapscott, "How blockchain is changing finance," *Harvard Business Review*, vol. 1, no. 9, pp. 2–5, 2017.

[19] T. Ahram, A. Sargolzaei, S. Sargolzaei, J. Daniels, and B. Amaba, "Blockchain technology innovations," in *2017 IEEE technology & engineering management conference (TEMSCON)*. IEEE, 2017, pp. 137–141.

[20] P. K. Wan, L. Huang, and H. Holtskog, "Blockchain-enabled information sharing within a supply chain: A systematic literature review," *IEEE access*, vol. 8, pp. 49 645–49 656, 2020.

[21] L. Su and H. Wang, "Analysis on electronic warehouse receipt of bulk commodity in supply chain finance practice," in *2020 International Conference on Computer Information and Big Data Applications (CIBDA)*. IEEE, 2020, pp. 33–36.

[22] M. Humayun, N. Jhanjhi, B. Hamid, and G. Ahmed, "Emerging smart logistics and transportation using iot and blockchain," *IEEE Internet of Things Magazine*, vol. 3, no. 2, pp. 58–62, 2020.

[23] A. Reyna, C. Martín, J. Chen, E. Soler, and M. Díaz, "On blockchain and its integration with iot. challenges and opportunities," *Future generation computer systems*, vol. 88, pp. 173–190, 2018.

[24] D. Shakhbulatov, J. Medina, Z. Dong, and R. Rojas-Cessa, "How blockchain enhances supply chain management: A survey," *IEEE Open Journal of the Computer Society*, vol. 1, pp. 230–249, 2020.

[25] S. P. Mohanty, V. P. Yanambaka, E. Kougianos, and D. Puthal, "Pufchain: A hardware-assisted blockchain for sustainable simultaneous device and data security in the internet of everything (ioe)," *IEEE Consumer Electronics Magazine*, vol. 9, no. 2, pp. 8–16, 2020.

[26] P. Saindane, Y. Jethani, P. Mahtani, C. Rohra, and P. Lund, "Blockchain: A solution for improved traceability with reduced counterfeits in supply chain of drugs," in *2020 International Conference on Electrotechnical Complexes and Systems (ICOECS)*. IEEE, 2020, pp. 1–5.

[27] A. U. Nwosu, S. Goyal, and P. Bedi, "Blockchain transforming cyber-attacks: healthcare industry," in *Innovations in Bio-Inspired Computing and Applications: Proceedings of the 11th International Conference on Innovations in Bio-Inspired Computing and Applications (IBICA 2020) held during December 16-18, 2020 11*. Springer, 2021, pp. 258–266.

[28] M. Crosby, P. Pattanayak, S. Verma, V. Kalyanaraman *et al.*, "Blockchain technology: Beyond bitcoin," *Applied innovation*, vol. 2, no. 6-10, p. 71, 2016.

[29] G. Baralla, A. Pinna, and G. Corrias, "Ensure traceability in european food supply chain by using a blockchain system," in *2019 IEEE/ACM 2nd International Workshop on Emerging Trends in*

*Software Engineering for Blockchain (WETSEB)*. IEEE, 2019, pp. 40–47.

[30] S. Mondal, K. P. Wijewardena, S. Karuppuswami, N. Kriti, D. Kumar, and P. Chahal, "Blockchain inspired rfid-based information architecture for food supply chain," *IEEE Internet of Things Journal*, vol. 6, no. 3, pp. 5803–5813, 2019.

[31] S. Naskar, P. Basu, and A. K. Sen, "A literature review of the emerging field of iot using rfid and its applications in supply chain management," *Securing the internet of things: concepts, methodologies, tools, and applications*, pp. 1664–1689, 2020.