

BLOCKCHAIN & AI-POWERED LOGISTICS SECURITY

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ABSTRACT

Information security and effective data searching are essential in today's logistics environment. This study introduces a novel use of Ant Colony Optimization (ACO) and Blockchain technology to improve data retrieval and secure logistical information. ACO is used to optimize data search procedures, guaranteeing quick and precise retrieval of logistics information. It is modeled after the foraging behavior of ants. At the same time, blockchain technology offers a strong security foundation that guarantees data immutability, transparency, and integrity. By combining these two cutting-edge approaches, we provide a solution that strengthens the security of the data against tampering and unwanted access while simultaneously optimizing the logistical data search process. The experimental findings show that the suggested method greatly improves data security and search efficiency, making it a workable answer to contemporary logistics problems.

I. INTRODUCTION

The logistics sector is essential to maintaining the efficient flow of products and services in the modern, globalized world. The amount and complexity of the data handled by the industry increase with its size. This data covers a wide range of topics, including customer information, delivery schedules, inventory management, and shipment tracking. It is crucial to make sure that this data is managed securely and effectively. However, these issues are frequently not well addressed by conventional data management techniques, which can result in inefficiencies and even security breaches. This study suggests a novel solution to these problems by combining blockchain technology with Ant Colony Optimization (ACO) to improve the

security and effectiveness of logistics information management. An efficient technique for resolving challenging optimization issues is Ant Colony Optimization, which draws inspiration from the ants' natural foraging activity. ACO can be used in logistics to streamline data search procedures, guaranteeing quicker and more precise information retrieval. In contrast, blockchain technology provides a safe and decentralized foundation for managing and storing data. Because of its intrinsic immutability, transparency, and cryptographic security, it's the perfect way to shield private logistics data from manipulation and unwanted access. We can increase trust and accountability by using Blockchain technology to produce a tamper-proof record of every logistics transaction.

II. RELATEDWORKS

1. Pâté, S., & Petro sky, N. (2016)

Title: Will blockchain technology revolutionize excipient supply chain management?

Merits: Demonstrated blockchain's ability to provide traceability and transparency in logistics.

Demerits: Lacked integration with AI for predictive threat detection and anomaly response.

2. Francisco, K., & Swanson, D. (2018)

Title:The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency.

Merits: Showed how blockchain improves supply chain transparency and reduces fraud.

Demerits: Focused on visibility, not on security threats or AI-driven risk mitigation.

3. Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019)

Title: Blockchain technology and its relationships to sustainable supply chain management

Merits: Provided a strong foundation for using blockchain in logistics with a focus on data integrity.

Demerits: Did not explore AI applications in logistics threat detection or prevention.

4. Nguyen, G. N., & Kim, S. (2020)

Title: AI-Based Anomaly Detection for Logistics Systems

Merits: Proposed an AI model using LSTM and clustering for anomaly detection in logistics operations.

Demerits: Operated independently of blockchain; lacked immutable data support.

5. Leng, J., Ruan, G., Jiang, P., Xu, K., Liu, Q., & Liu, Y. (2020)

Title: Blockchain-enabled intelligent manufacturing and logistics system

Merits: Integrated blockchain and AI to support secure logistics automation and predictive analytics.

Demerits: Implementation, complexity and scalability issues were not addressed fully.

6. Feng, T., Zhang, S., & Xie, F. (2021)

Title:Blockchain and Artificial Intelligence for Supply Chain Finance: A Literature Review

Merits: Reviewed applications of AI and blockchain in secure and efficient supply chain financing.

Demerits: Focused more on finance aspect rather than core logistics security.

7. Wamba, S. F., & Quiroz, M. M. (2021)

Title: Blockchain in the operations and supply chain management: Benefits, challenges and future research opportunities

Merits: Offered a roadmap for integrating blockchain into secure logistics workflows.

Demerits:The study was conceptual; real-world security use cases were limited.

III. SYSTEMANALYSIS

In the realm of logistics, current systems for managing information and securing data predominantly rely on traditional database

management systems (DBMS) and standard security protocols. Centralized databases, managed by a central authority, store logistics data in a single location, often leading to inefficiencies as the data volume grows, resulting in slower search operations and higher resource consumption. Traditional search algorithms, such as linear and binary searches, and indexing techniques like B-trees or hash indexing, can become less effective with large-scale and dynamic datasets. On the security front, these systems employ data encryption (e.g., AES) to protect data at rest and in transit, role-based access control (RBAC) to restrict access based on user roles, and audit logs to track data access and modifications. However, these measures are not foolproof. Centralized systems are vulnerable to single points of failure, making them susceptible to cyber-attacks, system crashes, and data loss. They also face scalability issues, requiring significant infrastructure upgrades to handle growing data volumes, and are prone to various security threats, including data breaches and insider attacks. Despite these efforts, ensuring data integrity, authenticity, and efficient data retrieval remains challenging. Emerging solutions, such as Ant Colony Optimization (ACO) for optimizing data search processes and Blockchain technology for decentralized and secure data management, offer promising alternatives to address the limitations of traditional logistics information management systems.

Limitations

Despite the implementation of the aforementioned mechanisms, existing systems exhibit several critical limitations:

1. Single Point of Failure

- Centralized databases are vulnerable to single points of failure, making them susceptible to cyber-attacks, system crashes, and data loss.

2. Scalability Issues

- As logistics operations grow, the volume of data increases exponentially, making it challenging for traditional systems to scale efficiently without any significant infrastructure upgrades.

3. Security Vulnerabilities

- Centralized systems are prone to various security threats, including data breaches, unauthorized access, and insider attacks. Ensuring data integrity and authenticity remains a persistent challenge.

Proposed System

The proposed system integrates Ant Colony Optimization (ACO) and Blockchain technology to address the inefficiencies and security vulnerabilities of traditional logistics information management systems. ACO, inspired by the natural foraging behavior of ants, is utilized to optimize data search processes, significantly enhancing search efficiency and accuracy. By employing ACO, the system can quickly find the most efficient paths for data retrieval, even in large and complex datasets. Concurrently, Blockchain technology provides a decentralized and secure framework for data storage and management. Its characteristics of immutability, transparency, and cryptographic security ensure that logistics data is protected from unauthorized access and tampering. By recording all transactions on a

tamper-proof ledger, Blockchain enhances data integrity and trust. The synergy between ACO and Blockchain creates a robust system where optimized data searching is paired with enhanced security measures. This integration not only streamlines logistics operations but also ensures that all data remains secure and verifiable, addressing the dual challenges of data search efficiency and security in modern logistics.

Advantages

Integrating Ant Colony Optimization (ACO) and Blockchain technology into logistics information management offers several significant advantages, addressing both efficiency and security concerns. Here are the key benefits of the proposed system:

1. Enhanced Search Efficiency

- **Optimal Path Finding:** ACO algorithms excel at finding the most efficient paths for data retrieval, reducing search times and improving accuracy. This leads to faster access to critical logistics information, enhancing overall operational efficiency.
- **Scalability:** The adaptive nature of ACO allows the system to scale effectively with increasing data volumes, maintaining high performance even as the dataset grows.

2. Improved Data Security

- **Decentralization:** Blockchain's decentralized architecture eliminates single points of failure, making the system more resilient to cyber-attacks and reducing the risk of data loss.

- **Immutable Records:** The immutability of Blockchain ensures that once data is recorded, it cannot be altered or deleted, providing a secure and tamper-proof record of all transactions.

3. Transparency and Trust

- **Auditability:** Blockchain's transparent ledger allows for easy auditing and tracking of all logistics transactions, fostering trust among stakeholders by ensuring data authenticity & accountability.
- **Traceability:** Every transaction is traceable, enabling stakeholders to verify the origins and movements of goods throughout the supply chain.

IV. IMPLEMENTATION

Modules:

1. Identity & Access Management (IAM) Module

- **Description:** Secures user roles and access across the logistics network.
- **Functions:**
 - Role-based access (supplier, transporter, admin, auditor).
 - Biometric or digital signature authentication.
 - Eid or PKI-based identity verification.

2. Smart Contract Management Module

- **Description:** Manages programmable rules and agreements in the supply chain using smart contracts.
- **Functions:**
 - Automates compliance, payment, and verification processes.

- Triggers alerts on security breaches or delivery failures.
- Enforces contract logic between parties.

3. Blockchain Ledger Module

- **Description:** Stores immutable records of all transactions, asset movements, and process events.
- **Functions:**
 - Tracks product journey from origin to delivery.
 - Logs AI-detected anomalies and actions taken.
 - Ensures tamper-proof audit trails.

4. AI-Based Anomaly Detection Module

- **Description:** Detects fraudulent or suspicious logistics events using machine learning.
- **Functions:**
 - Real-time sensor data analysis (temperature, GPS, door status).
 - Predictive modelling of potential theft/diversion.
 - Uses LSTM/CNN for route deviations and risk profiling.

5. Asset Tracking & IOT Integration Module

- **Description:** Integrates GPS, RFID, and other IOT devices to monitor logistics in real time.
- **Functions:**
 - Monitors asset movement, environmental conditions, and unauthorized access.
 - Sends data to AI engine and stores events on the blockchain.

- Supports edge computing for quick responses.

Methodology: The methodology outlines the end-to-end workflow, from data collection to secure delivery verification.

Step 1: Stakeholder Registration and Access Control

- All the logistics stakeholders (manufacturers, suppliers, shippers, auditors) register through a secure portal.
- Identity verification is done via digital ID or PKI (Public Key Infrastructure).
- Access is managed through role-based access control (RBAC) to ensure only authorized users interact with specific modules.

Step 2: Smart Contract Deployment

- **Smart contracts** are developed and deployed on a blockchain network (e.g., Ethereum or Hyper ledger).
- These contracts encode logistics rules such as:
 - Temperature thresholds.
 - Defencing routes.
 - Delivery time windows.
 - Payment release upon successful delivery.

Step 3: IOT-Enabled Asset Tracking

- Goods are tagged with IOT devices (e.g. GPSTrackers, RFID, temperature sensors).
- These devices continuously stream real-time data to the system.
- Data includes location, temperature, humidity, motion status, and container breach detection.

Step 4: AI-Based Risk and Anomaly Detection

- Collected IOT data is analysed using AI/ML algorithms (e.g., LSTM, Random Forest, and CNN).
- The AI models perform:
 - **Anomaly detection** (e.g., sudden temperature spike, route deviation).
 - **Predictive analytics** (e.g., likelihood of delay or cargo tampering).
- Anomalies are immediately flagged and logged onto the blockchain for traceability.

Step5: Blockchain Logging and Validation

- All key events (shipment start, anomalies, approvals, handoffs) are recorded as transactions on the blockchain.
- Each transaction includes:
 - Cryptographic hash of data.
 - Timestamp.
 - Event metadata.

V.RESULTS



Fig 1

In above screen click on ‘Register Here’ link to get below page.

New User Signup Screen

Username

Password

Contact No

Email ID

Address

Register

Fig 2

In above screen user is entering sign up details and then press button to get below page.

New User Signup Screen

Signup process completed and record saved in Blockchain

tionHash': HexBytes('0xb4f34473b3669eb11914cfa472a4596ea4e0fbb9ff100297
HexBytes('0xa8f24ba67211c7f41528ba08a87f26b7b790a18ecb21cef998e0ecfibe
86f7db107b33b4fd681943433b33f9', 'to': '0xd374eb05bd6187d6cf905d7bbd85f2
'seed': 155749, 'contractAddress': None, 'logs': [AttributeDict({'logIndex': 0, 'transa
exBytes('0xb4f34473b3669eb11914cfa472a4596ea4e0fbb9ff10029735f8d1c5abd
('0xa8f24ba67211c7f41528ba08a87f26b7b790a18ecb21cef998e0ecfibe9d7', 'l
'0xd374Cb05bd6187D6cF905D7bBD85f2b704fBD29', 'data': '0x', 'to
[HexBytes('0x1ed675bb725b3a8b0434b9ee956fe05e4coe79f9dc67c3fia717a5l
oo
'logsBloom':
oo

Username

Password

Contact No

Email ID

Fig 3

In above screen user sign up details saved in Blockchain and for your understanding I am displaying all response returned from Blockchain after scoring record and in above screen can see transaction no, block no, hash code and many other details. Now click on ‘User Login’ link to get below page

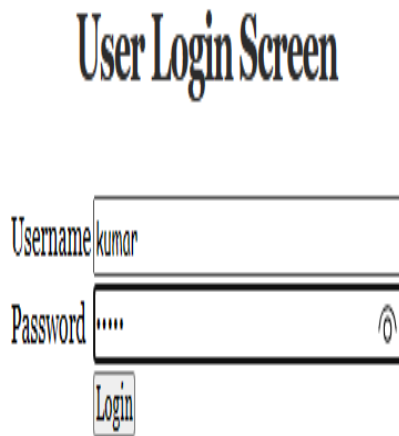


Fig 4

In above screen user is login and after login will get below page.



Fig 5

In above screen click on 'Upload Encrypted Chunks File' link to get below page to upload file and this file can be any text file or your logistic file

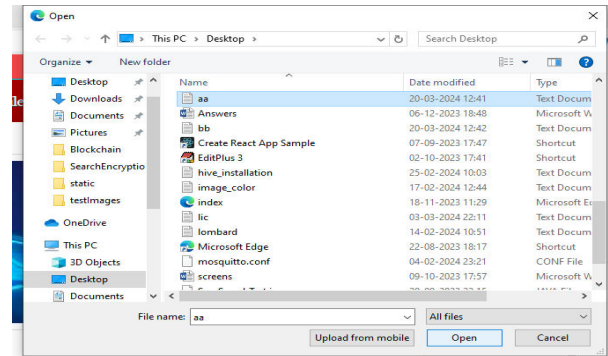


Fig 6

In above screen selecting and uploading aa.txt file and then click on 'Open' and 'submit' button to convert file into encrypted chunks and then generate trapdoor and then store trapdoor in Blockchain and encrypted chunks in cloud and then will get below output.

Uploader Name	Filename	Uploading Date	Chunk Name	Encrypted Chunk Data
kumar	aa.txt	2024-03-20	aa.txt_block_0	b'%%\xbbl\x14q!\xd2!\xd3w!\xc3!\xa0Pj#\!\xd8pCcK!\xo8!\xbbl'
kumar	aa.txt	2024-03-20	aa.txt_block_1	b'? !\xb9!\x19hv!\xda!\x94q!\xc2!\xb5!\x18?!\x8cmTe!\x03!\x02!\xb3'
kumar	aa.txt	2024-03-20	aa.txt_block_2	b'!\x0e!\xc0!\x~!\xd4!\xd1i!\xc6!\xf0Y4\$!\xd8pNe!\x03!\x03!\xcbe'

Fig 7

In above screen from uploaded file 3 chunks are created and then can see encrypted data from each chunk and then can see hash code of each chunks and similarly you can upload any number of text file. Here we need to divide file into blocks so we need to use only text file. Here we are using free education purpose Ethereum tool so its gas price will be less so try to upload small size files. Now click on 'View Blocks' to retrieve all blocks files and trapdoor from Blockchain

Uploader Name	File Chunks	Trapdoor	Upload Date
kumar	aa.txt_block_0	fa04eed0fba186a2e5d4b9c169a53482d659de397c75df8fba599de6d7e2b394126a0e52e757e3d535d0f0bd33ce	2024-03-20
	aa.txt_block_2		
kumar	bb.txt_block_0	8820aa5e3dcff9b58f799e02a7478223eeeb4347b0dd260f6b7ee9430755dd1352975c569d5f77dd93329526b0442a7	2024-03-20
	bb.txt_block_2		

Fig 8

In above screen can see name of uploaded and then can see name of each file in each row and each file will have multiple chunks names and then can see encrypted trapdoor which will search by user in encrypted mode only and then can see date of file upload. Now click on ‘ACO Based File Search’ link to get below screen to search file



Trapdoor Search Using Ant Colony

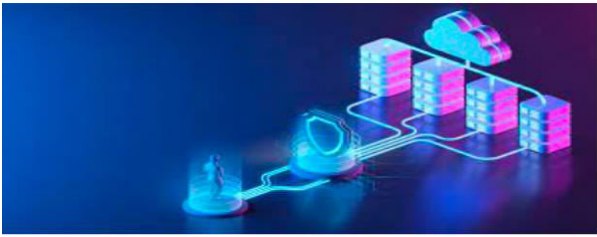
Search Query

python encrypted

Submit

Fig 9

In above screen i gave some keywords and then press button to get list of all files which contains those words



Uploader Name	Filename	Download File
kumar	aa.txt_block_0	Click Here
kumar	bb.txt_block_0	Click Here

Fig 10

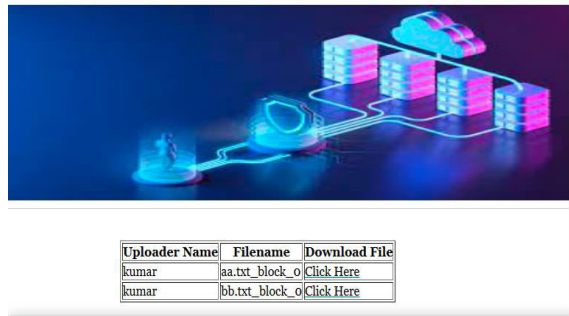
In above screen user can see list of all searched file and then click on ‘Click Here’ link to download desired file in decrypted format



Uploader Name	Filename	Download File
kumar	aa.txt_block_0	Click Here
kumar	bb.txt_block_0	Click Here

Fig 11

In above screen in right side panel can see file is downloaded and now open that file to view text in decrypted format in below screen



Uploader Name	Filename	Download File
kumar	aa.txt_block_0	Click Here
kumar	bb.txt_block_0	Click Here

aa (1) - Notepad

File Edit Format View Help

cryptographic technique that allows users to search specific information in encrypted content w
to create a map between the plaintext value written to a field and the encrypted value stored i
SE schemes must meet the following requirement

Fig 12

In above screen can see file text in decrypted format.

Similarly by following above screens you can manage encrypted file in cloud and searchable trapdoor in Blockchain to provide security to user data.

VI. CONCLUSION

The efficiency and security of data searches in logistics information management are two problems that can be effectively resolved by combining blockchain technology with Ant Colony Optimization (ACO). Even while they work, traditional systems frequently can't handle the vulnerabilities and complexity that come with contemporary logistical operations. The suggested solution makes use of ACO's advantages to streamline data retrieval procedures, guaranteeing quick and precise access to logistical data. At the same time, Blockchain technology offers a strong, decentralized architecture that, thanks to its immutable ledger and cryptographic protocols, ensures data security, integrity, and transparency. Improved search efficiency, better data security, greater transparency and stakeholder trust, lower operating costs, and increased system resilience are just a few of the significant benefits that come with this novel method. The solution promotes more dependable and effective logistics operations by automating procedures and guaranteeing data validity, meeting both present demands and future scalability requirements. The outcomes of the trial have shown how effective this integrated system is and how it has the ability to completely transform logistics information management. Such cutting-edge technologies are becoming more and more necessary as logistics

networks continue to get more complex. In addition to satisfying this need, the suggested combination of ACO and Blockchain establishes a new benchmark for safe and effective logistics data management.

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