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Jewellery Supply Chain Management using Hyperledger Fabric

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***Abstract*— Quality and quantity plays a vital role in Jewellery stores, the main part for a store is maintaining the quality and quantity of the product. The solution for this is to use Blockchain. Blockchain was firstly used for maintaining records or transactions of the peers. Blockchain is highly secured technology which provides distributed records maintenance and advanced level of encryption and also provides distributed database. In this paper we have proposed a proper system to maintain proper traceability and full transparency in supply chain, the system provides proper maintenance of all the records maintained by the parties. We designed this system very intelligently to provide an architecture for three main factors, the manufacturers, middlemen and store owners, who will get proper information about their assets or products at any time. This system also contains certifying authorities that will help maintain authenticity in the system. Private blockchain gives us various advantages such as maintaining proper traceability for authenticated users and maintaining the records in private databases with security features like hashing. This system helps us solve main problems in the supply chain of assets i.e proper tracking of packages which in turn helps us maintain good quality and quantity of products.**

Keywords—Blockchain, hyperledger fabric, supply chain, private blockchain,traceability, chaincode, peers, organizations.

I. INTRODUCTION

From the past few years, the development of technology is at its peak, but we can't compromise the records required to maintain a product supply chain. Which in turn helps us maintain tracking and quality of our products. Besides this digitalization is happening rapidly and development is also happening fast which gets a great curiosity of manufacturers to automate their management tasks.

Products such as gold, diamond are transported and distributed worldwide, so the guarantee of quality and quantity is required. Therefore, the product supply chain system must have a transparent mechanism and maintain safety and traceability of products. This are some complex problems faced by various traditional systems, which inturn can't meet the requirement criterias. These problems can be solved by current technologies like blockchain, AI and all other technologies.

We can build the product supply chain in two ways : distributed model or traditional client-server model. The Client-server model is the traditional, centralized architecture which typically stores data in one main server and then distributes them to other servers for maintaining its state, this type of architecture uses third parties to store and maintain the records or tracks of the products. This type of style doesn't optimize itself for a secure way of maintenance. Also, the data manipulation can easily happen if the main server gets hacked or data can be easily breached. So this type of model can't satisfy the main requirements of transparency and traceability.

Blockchain solves all the above problems in an efficient way, this technology gives us an distributed peer to peer architecture, which enhances the traditional model giving us an ease in scalability, enhances reliability, improves management of system, and increases confidence in customers. This technology stores the data in form of blocks which are interlink with each other and can be expanded over time. Also once the data stored is immutable, if an hacker tries to tamper with the data, he breaks the chaining of blocks and the blocks are verified via consensus mechanism which helps maintain the integrity and authenticity of users and data. The blocks are encrypted via digital signature of sender and decrypted via receivers digital signatures. The transaction in blocks are also encrypted via hashing algorithms like SHA-256.

Therefore, because of all above reasons blockchain technology suits great or fits great in the supply chain market giving us an advantage of tracking, scaling and maintaining an tamper proof record.

II. LITERATURE SURVEY

The investigation into blockchain-based traceability systems within the supply chain marks a significant stride towards enhancing product traceability and cultivating stakeholder trust[2]. With a focus on establishing a sustainable model, this initiative aims to address challenges related to the

authenticity of product information, underscoring the critical role of trust in supply chain dynamics[1].

At the heart of this exploration lies the integration of Hyperledger Fabric technology, harnessing the potential of blockchain to ensure seamless data traceability[1]. Departing from conventional supply chain infrastructures, this proposed framework champions transparency and security through decentralized ledger technology[3].

A crucial aspect of evaluating such a system involves employing Hyperledger Caliper to scrutinize transaction throughput, latency, and resource usage. Notably, the findings reveal a direct relationship between transaction volume and resource consumption, signaling potential scalability issues under increased workloads[2].

Furthermore, this inquiry underscores the paramount importance of bolstering supply chain security. By demonstrating resilience against common threats such as man-in-the-middle and replay attacks, the study reaffirms blockchain's ability to safeguard data integrity throughout the supply chain ecosystem[1].

In comparison with previous research, this study delineates unique contributions, shedding light on advancements in blockchain implementation within supply chain contexts[1]. From assessing performance to analyzing security measures, the discourse underscores the transformative potential of blockchain-based traceability systems in promoting transparency, enhancing security, and upholding data integrity within the intricate fabric of the tea supply chain[9].

Going beyond system implementation, this research delves into the mechanics of smart transactions within the blockchain realm[1]. While refraining from actual system construction, the study illuminates the process of transitioning existing systems onto blockchain infrastructure, showcasing the promise of the Hyperledger Blockchain Platform[6].

In summary, the literature survey encapsulates the evolving landscape of blockchain technology, particularly in the domains of traceability and supply chain management. By highlighting the significance of Hyperledger Fabric and Hyperledger Composer, it underscores the pivotal role of blockchain in addressing the myriad challenges faced by modern supply chains, ranging from information asymmetry to product authenticity and beyond.

III. KEY CONCEPTS

A. *Hyperledger Fabric Network Setup:*

Create a Hyperledger Fabric network with the required organizations (Raw Material Sourcing, Manufacturing, Logistics, Retail, Supplier, and Customer).

Define the channel structure and configure the necessary access control policies for each organization.

Set up the appropriate certificate authorities (CAs) to manage the identities of participants in the network.

B. *Supply Chain Management:*

Design and develop smart contracts to manage the flow of raw materials, track the manufacturing process, handle logistics, and integrate with retail operations.

Implement functions to record supply chain events, such as raw material procurement, production milestones, shipment details, and product delivery.

Ensure traceability by maintaining a comprehensive history of the product's journey through the supply chain.

C. *Customer Interaction:*

Design and develop a user-friendly web application or mobile app as the customer-facing interface.

Implement functionalities for customers to browse the catalog of verified products, view product details, and place orders.

Integrate the reward points system, allowing customers to earn points for their purchases.

D. *Integration and Deployment:*

Integrate the supply chain management, customer interaction and managing assets into a cohesive system.

Deploy the Hyperledger Fabric network, smart contracts, and front-end applications on a suitable infrastructure, such as a cloud platform or on-premises servers.

Implement security measures, access control, and monitoring solutions to ensure the system's reliability and resilience.

E. *Testing and Optimization:*

Conduct comprehensive testing, including unit tests, integration tests, and end-to-end tests, to verify the system's functionality and performance.

Continuously monitor the system's performance and address any bottlenecks or issues that arise.

Implement optimization strategies, such as fine-tuning smart contract logic, improving data storage and retrieval, and enhancing the user experience.

F. *Ongoing Maintenance and Updates:*

Establish a maintenance and update plan to address security vulnerabilities, bug fixes, and new feature requirements.

Implement a governance model to manage the evolution of the system, including the inclusion of new participants, updates to smart contracts, and changes to the overall system architecture.

IV. PROPOSED METHODOLOGY

A. *Architecture -*

The basic architecture is simply divided into two organizations : The main Supplier and the second is distributor, retailer and stores.

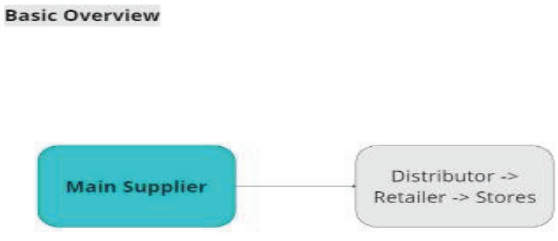

Fig. 1. Distribution of Organizations

The four layers are as follows -

Business layer :

The entire business model is listed in this section, as the model supports two main organizations. The main supplier is the organization which mines or creates the supply of the product. The main supplier is the origin or starting point of the supply chain and other organizations are distributors and retailers which maintain the supply chain towards the store, the store owner is the end point of the supply chain.

Traceability layer :

All information required relevant to the product supply chain is stored in the section.Information includes the main supplier info. Transportation records, storage records, the retailer, the store owner and the distributor information.

Blockchain layer :

This layer performs the traceability process of the products. The smart contract helps us interact with the organization with the interface of channels. To maintain authenticity, every peer has a certifying authority which helps maintain their own record and trace the supply chain.

Application layer :

This layer is responsible for user interaction and displays all the required information to the users.

User Interface (UI) -

At the forefront of the application layer is a user-friendly interface that provides intuitive access to the system's features and capabilities. Leveraging modern web development frameworks and design principles, the UI offers a visually appealing and responsive platform for users to navigate through the supply chain data, initiate transactions, and access relevant information with ease.

Transaction Management -

The application layer facilitates the initiation, processing, and verification of transactions within the blockchain network. Through a series of interactive forms and interfaces, users can submit transaction requests, specify transaction details, and track the status of ongoing transactions in real-time. Smart contract functionality ensures that transactions are executed autonomously and transparently, adhering to predefined business logic and rules.

Supply Chain Visualization -

One of the key components of the application layer is the visualization of the Jewellery supply chain. Utilizing interactive maps, timelines, and graphs, stakeholders can gain insights into the journey of precious metals and gemstones from their origin to the final product in the Jewellery shop. This visualization enhances transparency and traceability, empowering users to monitor the flow of assets and identify potential bottlenecks or inefficiencies within the supply chain.

Asset Tracking and Management -

The application layer provides robust tools for tracking and managing assets throughout their lifecycle. From the moment raw materials are sourced to the creation of finished products, stakeholders can leverage the system to monitor the movement, storage, and transformation of assets at each stage of the supply chain. Real-time updates and notifications ensure that stakeholders remain informed about the status and location of assets, enabling proactive decision-making and risk management.

Compliance and Reporting -

Compliance with regulatory requirements and industry standards is paramount in the Jewellery supply chain. The application layer facilitates regulatory compliance by generating comprehensive reports, audits, and documentation that demonstrate adherence to relevant laws and regulations. Through customizable reporting templates and automated workflows, stakeholders can efficiently compile and submit compliance-related information to regulatory authorities, fostering trust and credibility within the industry.

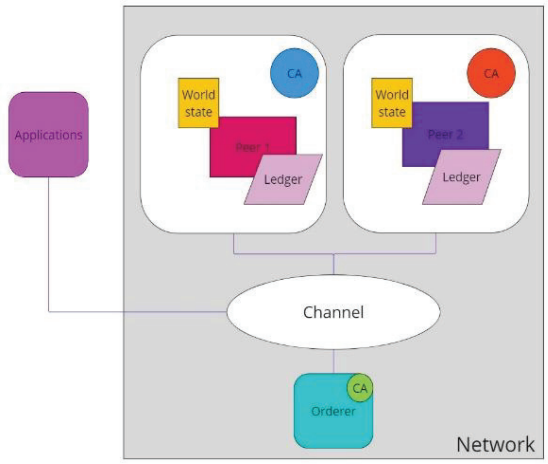

Fig. 2. The proposed model working architecture

B. System Objective & Stakeholders

The proposed system is to implement a blockchain-based system using Hyperledger Fabric to create a de-centralised and tamper-resistant ledger for tracking the journey of gold and diamonds from their origin to the final product in the jewellery shop. This system will enhance transparency, eliminate counterfeit products, and ensure ethical sourcing, ultimately building trust with customers.

1) Objectives :

The main objective of this project was to maintain traceability, integrity and authenticity.

Traceability :

Implement a blockchain solution that enables real-time tracking of gold and diamonds, providing stakeholders with a transparent view of the entire supply chain.

Authentication :

Use smart contracts to verify the authenticity of precious metals and gemstones at each stage of the supply chain, preventing the circulation of counterfeit products.

Efficient Collaboration :

Utilize Hyperledger Fabric's permissioned blockchain to facilitate secure and efficient communication and transactions among different entities in the supply chain.

Data Integrity :

Ensure the immutability of data on the blockchain to prevent tampering and unauthorized access, maintaining the integrity of the supply chain records.

2) Stakeholders:

Jewellery Shop Owners/Managers :

Responsible for the overall success and integration of the blockchain-based supply chain tracking system in the Jewellery shop.

Customers :

End-users who benefit from increased transparency and assurance regarding the authenticity and ethical sourcing of gold and diamonds.

Blockchain Developers :

Professionals responsible for designing, developing, and maintaining the Hyperledger Fabric blockchain network, including smart contracts and overall architecture.

Supply Chain Managers :

Oversee the implementation of the blockchain solution in the Jewellery supply chain, ensuring adherence to ethical sourcing practices and efficient tracking of materials.

Regulatory Authorities :

Depending on the jurisdiction, regulatory bodies may have an interest in ensuring compliance with laws and regulations related to the sourcing and trading of precious metals and gemstones.

V. RESULTS AND OUTCOME

The implementation of the Jewellery supply chain management system over hyperledger fabric gives us significant results, achieving transparency , traceability and efficiency. The key outcomes are as follows

Transparency and traceability :

All the records of transactions were successfully recorded over the blockchain network enhancing the traceability and providing us with transparency within the organization.

Improved transaction efficiency :

Implementation of chaincode in the system enhances the utilization of resources and provides us with automation for storing and sorting of transactions (records of assets) reducing time consumption.

Data integrity and Security :

The use of hyperledger fabric gives us an advantage over traditional systems providing a layer of security that only authenticate users are granted with the access.An additional security layer is provided by digital signature to verify and validate the peers present in the network.

The Jewellery system works mainly on the following Chaincode -

Product_Contract.ts :

This contract is the main contract that controls all the activities in the network i.e Creating product, maintaining product catalog by calling the catalog contract and reading the products as displayed in fig 3.

```
@Info({title: 'ProductSupplyChain', description: 'Smart Contract for handling product supply chain.' })
export class ProductSupplyChainContract extends Contract {
    @Transaction(false)
    @Returns('boolean')
    public async productExists(ctx: Context, productId: string): Promise<boolean> {
        const data = await ctx.stub.getState(productId);
        return (!!data && data.length > 0);
    }

    @Transaction()
    public async createProduct(ctx: Context, productJson: string): Promise<void> {
        const product = JSON.parse(productJson) as Product;

        const exists: boolean = await this.productExists(ctx, product.id);
        if (exists) {
            throw new Error(`The product ${product.id} already exists.`);
        }

        this.requireField(product.id, 'id');
        this.requireField(product.name, 'name');
        this.requireField(product.barcode, 'barcode');
        this.requireField(product.placeOfOrigin, 'placeOfOrigin');
        this.requireField(product.productionDate, 'productionDate');
        this.requireField(product.expirationDate, 'expirationDate');
        this.requireField(product.unitQuantity, 'unitQuantity');
        this.requireField(product.unitQuantityType, 'unitQuantityType');
        this.requireField(product.unitPrice, 'unitPrice');
        this.requireField(product.category, 'category');
        this.requireField(product.locationData.current.location, 'locationData.current.location');
        this.requireField(product.locationData.current.arrivalDate, 'locationData.current.arrivalDate');
        const buffer = Buffer.from(JSON.stringify(product));
        await ctx.stub.putState(product.id, buffer);
    }

    @Transaction()
    public async shipProductTo(ctx: Context, productId: string, newLocation: string, arrivalDate: string): Promise
        const exists: boolean = await this.productExists(ctx, productId);
        if (!exists) {
            throw new Error(`The product ${productId} does not exist.`);
        }

        this.requireField(newLocation, 'newLocation');
        this.requireField(arrivalDate, 'arrivalDate');

        const product = await this.readProduct(ctx, productId);

        product.locationData.previous.push(new ProductLocationEntry({
            arrivalDate: product.locationData.current.arrivalDate,
            location: product.locationData.current.location
        }));
        product.locationData.current.arrivalDate = arrivalDate;
        product.locationData.current.location = newLocation;

        const buffer = Buffer.from(JSON.stringify(product));
        await ctx.stub.putState(productId, buffer);
    }
    @Transaction(false)
    @Returns('Product')
    public async getProduct(ctx: Context, productId: string): Promise<Product> {
        const exists: boolean = await this.productExists(ctx, productId);
        if (!exists) {
            throw new Error(`The product ${productId} does not exist.`);
        }

        return this.readProduct(ctx, productId);
    }

    @Transaction(false)
    @Returns('ProductHistory')
    public async getProductWithHistory(ctx: Context, productId: string): Promise<ProductWithHistory> {
        const exists: boolean = await this.productExists(ctx, productId);
        if (!exists) {
            throw new Error(`The product ${productId} does not exist.`);
        }

        const product = await this.readProduct(ctx, productId);
        const productWithHistory = new ProductWithHistory(product);
        productWithHistory.componentProducts = [];

        for (const childProductId of product.componentProductIds) {
            const childProduct = await this.readProduct(ctx, childProductId);
            productWithHistory.componentProducts.push(childProduct);
        }

        return productWithHistory;
    }
```

Fig. 3. Chaincode for supply chain Management

Roles.ts :

The roles are defined in “roles.ts”, which helps in maintaining role based authentication and access control over the network as displayed in fig 4.

```
export const ORG_MANAGER_ROLE = 'manager';
export const ORG_EMPLOYEE_ROLE = 'employee';
export const CLIENT = 'client';
```

Fig. 4. Roles in system

Running up the network :

Before executing the system, we need to initialize the network which is done by using “./network.sh up” command as displayed in fig 5.

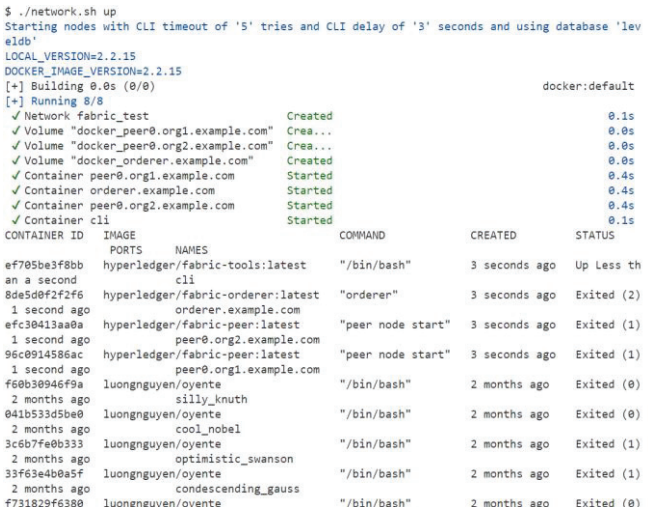

Fig. 5. Starting the Network

Product Information :

The products are stored in a network i.e on blockchain which is shown in fig 6.


```
"result": {
    "barcode": "1234567890",
    "batchQuantity": 1000,
    "category": "Gold",
    "componentProductIds": [],
    "expirationDate": "2022-06-24T18:25:43.511Z",
    "id": "1001",
    "locationData": {
        "current": {
            "arrivalDate": "2021-06-30T18:00:58.511Z",
            "location": "Swiss Miners, Marton, ON, Swizerland"
        },
        "previous": []
    },
    "misc": "{}",
    "name": "Diamond",
    "placeOfOrigin": "Swiss, ON, Swizerland",
    "productionDate": "2021-06-24T18:25:43.511Z",
    "unitPrice": "$2255.00",
    "unitQuantity": 300,
    "unitQuantityType": "mg",
    "variety": null
}
```


Fig. 6. Product Information

Comparison between traditional & proposed system :

TABLE I. COMPARISON OF TRADITIONAL SYSTEM & PROPOSED SYSTEM

Feature	Traditional Supply Chain	Blockchain-Based Supply Chain (Hyperledger Fabric)
Transparency	Limited visibility across the supply chain	Full end-to-end visibility and transparency
Traceability	Difficult to trace products from origin to final consumer	Comprehensive, real-time traceability from raw material to consumer
Counterfeit Prevention & Security	Difficult to detect and prevent counterfeit products & unauthorize access present	Tamper-proof records reducing counterfeit risk & no unauthorize access
Customer Confidence & trust	Low confidence & trust due to lack of product verification	High confidence & trust with verifiable product information
Cost Efficiency	High operational costs due to manual interventions	Reduced operational costs through automation and efficiency
Audit and Verification	Time-consuming and costly audits	Simplified and cost-effective audits with immutable records

VI. CONCLUSION

In conclusion, the application of Hyperledger Fabric blockchain technology in the Jewellery supply chain management system offers a transformative solution to the industry's pressing challenges. By harnessing the power of distributed ledger technology, this proposed system addresses the critical need for transparency, authenticity, and traceability throughout the journey of precious metals like gold and gemstones like diamonds.

The existing centralized systems fall short in ensuring the integrity of the supply chain, leaving room for counterfeit products, unethical practices, and a lack of visibility into the production process. In contrast, the proposed blockchain-based system leverages Hyperledger Fabric's decentralized architecture to create a tamper-resistant ledger, enabling real-time tracking of assets from their origin to the final product in the Jewellery shop.

The key objectives of the project, including traceability, authentication, efficient collaboration, and data integrity, are effectively achieved through the implementation of smart contracts, permissioned blockchain, and modular architecture. By providing stakeholders with a transparent view of the entire supply chain, the system instils trust and confidence among customers, ensuring the authenticity and ethical sourcing of gold and diamonds.

In light of the literature survey, which highlights the advancements and challenges in blockchain-based traceability systems within the supply chain, it is evident that the proposed system represents a significant stride towards enhancing product traceability and cultivating stakeholder trust in the Jewellery industry. Moving forward, continued research and development efforts are essential to refine and optimize the system, further unlocking its transformative potential in promoting transparency, enhancing security, and upholding data integrity within the intricate fabric of the Jewellery supply chain.

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