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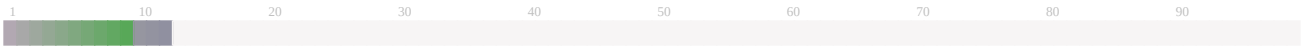

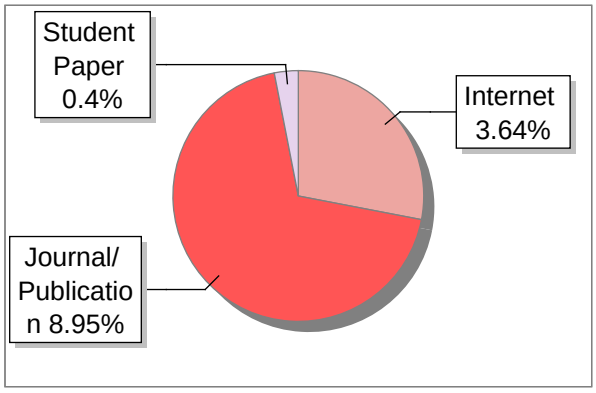

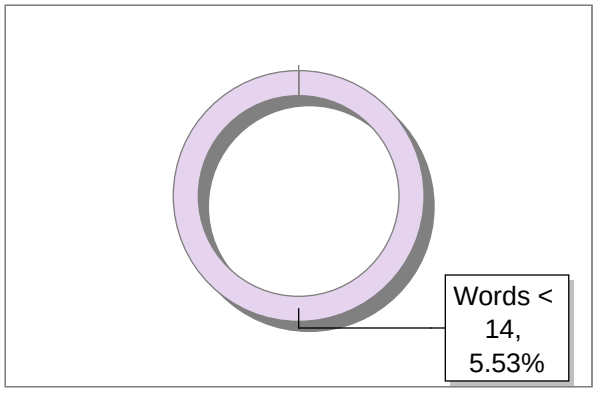

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Leveraging Blockchain Technology for Enhancing Security and Avoiding Counterfeit in Medical Supply Chain Management

Dr. Suhasini Monga[1,*], Mr. Somil Gambhir[2], Ms. Sonal[3]
Chitkara University Institute of Engineering and Technology
Chitkara University, Rajpura (Punjab)
suhasini.monga@gmail.com, gambhirsomil7@gmail.com
sonal27bnsl@gmail.com

Abstract. This study focuses on the challenges that medical supply chain management faces, such as inefficiencies, lack of transparency, fraudulent medicines, and inadequate customer safeguards. To address these issues, the study proposes an innovative blockchain model that aims to drastically transform the medical supply chain. The proposed blockchain model places significant emphasis on transparency, enabling users to access information about the production and composition of raw materials. Blockchain, a decentralized and immutable ledger, enhances the supply chain for medical supplies by providing transparency, traceability, and security. To be able to increase consumer satisfaction, this model incorporates features like a secure payment mechanism and a return system in addition to addressing conventional obstacles. Transparency is emphasized in the suggested paradigm, giving users access to data regarding the origins and composition of raw materials. This study makes a substantial contribution to the current conversations around improving the effectiveness, openness, and general integrity of medical supply chains. By addressing problems including inefficiencies, a lack of transparency, and inadequate client safeguards, the study suggests a novel blockchain approach to transform the management of the medical supply chain. Additionally, a comprehensive evaluation of the literature on blockchain research in medical supply chains is done in this study report. The analysis emphasizes how blockchain technology might help with issues like transparency and traceability that medical supply chains.

Keywords: Medical Supply Chain, Blockchain, Decentralization, Counterfeit Drugs, Transparency

1 Introduction

• Virtual currencies like Bitcoin are typically linked to blockchain technology. It is a transnational computer network that maintains and verifies the accuracy of a distributed database of transaction records. The records are governed by a large community rather than a single central authority, such as a bank; no individual has control over them, and transaction histories cannot be changed or removed. Data cannot be changed like it would in a conventional centralized database due to the distributed structure of blockchain and peer-confirmed guarantees [1].

Blockchain technology has since been applied in a number of sectors, including business, healthcare, and finance. Blockchain technology is more dependable, transparent, and traceable in business operations when it is decentralised, which means that all transactions are ongoing, recorded, unchangeable, and dispersed among all network nodes.

A few of the major participants in the supply chain that are involved in the production process are producers, distributors, and retailers.Distribution, and sale of pharmaceuticals. In that particular business cycle, the flow of information, the flow of services, and the transfer of different commodities between different entities all require a secure network. In every industry, a weak supply chain invites major issues, but in the medical field, the health of patients is put at even higher danger. The medical business requires optimized solutions that help simplify a variety of supply chain tasks and procedures. A pharmaceutical company's disdain for supply chain security is strongly correlated with the level of health danger it poses, much like the pharmaceutical industry,this is because weakening a chain can also jeopardize the health of its patients. Getting a novel product (medicine) to market after a drawn-out process of drug formulation, clinical trials, and final development is one of the largest challenges facing the pharmaceutical business. Given the ongoing COVID-19 pandemic, a larger labor force could potentially accelerate the virus's transmission [2].

Nonetheless, medication shortages often result from existing loopholes, emphasizing the need for drug managers to possess a comprehensive understanding of available inventory for medication creation. This understanding is crucial in preventing the issue of drug shortages. To ascertain the legitimacy of pharmaceutical suppliers, wholesalers must be vigilant. One fake or inferior medication out of every 10 is common [4]. These counterfeit drugs' mixture of toxic and frequently impure active ingredients can have an instantaneous detrimental effect on patients' health, impairing the actual medication's appropriate functioning in certain cases [5]. Blockchain technology can tackle a number of problems, such as counterfeiting and efficient inventory control to satisfy consumer demand. Blockchain is a supply chain transparency tool that consists of a network of interconnected systems called blocks.

1.1 Contributions

The primary contributions of this study are as follows:

- A thorough review of existing literature on blockchain applications in medical supply chain management was conducted that underpins the development and significance of our proposed model.
- A novel decentralized blockchain model for managing data, ensuring secure and transparent transactions among stakeholders in a medical supply chain management has been presented in this paper.
- Future implementation of the suggested decentralized approach is planned with the goal of confirming the paradigm's viability and effectiveness in actual medical supply chain management..

2 Literature Review

Ahmad Musamih et al.(2021) highlighting the intricate network of healthcare, Using blockchain technology is one cutting-edge way to revolutionise supply chain management. Centralised track and trace systems are currently used in pharmaceutical supply chains, yet they have issues with data privacy,openness, and validity. The authors provide a workaround for these drawbacks that makes use of Ethereum blockchain decentralized off-chain storage and smart contracts [6].

Muhammed Azeem Akbar et al.(2022) discusses that the medical field can reap benefits from blockchain technology, such as better supply chain management and increased productivity, while also improving data security and saving money and time. Key success elements and implementation challenges, particularly supply chain management-related ones, are intended to be addressed by the medical blockchain's suggested maturity model [7].

Faisal Jamil et al.(2019) shows how the pharmaceutical business works to stop the sale of fake medications. can give the medication supply chain security, visibility, and traceability.The proposed system would track the drugs from manufacturing to delivery and record the effects of the drugs on patients for future statistics. Blockchain technology offers increased trust and transparency, traceability, privacy protection, extended security, and a database for future statistics [4].

Ijazul Haq et al.(2018) suggests a unique paradigm for managing the application time-limited blockchain Integrity of medicinal supply chains using blockchain technology in smart hospitals. The public's health is seriously at stake since counterfeit medications may have distinct side effects from those of real medications. The suggested solution makes use of smart contracts and fabric to provide a safe medication supply chain and facilitate patient health record and medication electronic access. Calliper was used as a benchmarking tool to test and assess the system[5].

Feroz Khan et al.(2022) provides a framework for the adoption of circular supply chain management (CSCM) in the pharmaceutical industry, focusing on overcoming barriers and leveraging enablers. It utilizes a new hybrid methodology to analyze and prioritize barriers and enablers, employing fuzzy multi-criteria decision-making (MCDM) and fuzzy quality function deployment (FQFD) techniques. This approach facilitates the implementation of CSCM by offering a systematic way to address challenges and capitalize on opportunities within the pharmaceutical supply chain [8].

Yassine Sabri et al.(2022) proposes Like the pharmaceutical industry, the level of health danger posed by a pharmaceutical corporation strongly correlates with its disdain for supply chain security. A designated authority, working under government supervision, assigns unique IDs to legitimate manufacturers and distributors, setting uniform standards for their operations [3].

3 Pitfalls in Medical Supply Chain Management

To regulate the production and movement of medications, all parties involved in the present medical supply chain management—manufacturers, distributors, and other parties—are creating their own procedures and frameworks. Just two of the numerous issues that come up when there is a there's not enough of supply chain visibility are a manufacturing company's capacity to track goods held in warehouses in semi-completed and final forms and the importance of inventory management in a multi-layered supply chain. An abundance of problems stem from inefficient inventory management, including as under- and overstocking, waste of resources, lower profit margins, higher costs, and an unbalanced business process overall. This is particularly true if the number of semi-finished and final goods, how much raw material there is required, and how much raw material there is on hand are unclear to the producer and distributor [3]. The current situation is full of difficulties and barriers. Table 1 shows common pitfalls in managing the medical supply chain..

4 Blockchain Technology: A pivot in MSCM

Numerous fundamental technologies, including distributed consensus mechanisms, digital signatures, and cryptographic hashes, are integrated resulting in blockchain technology. A list of blocks is formed by adding transactions that are in the commit mode to blockchain, which could be regarded as a distributed ledger [9]. Each transaction is called a block, which is added to a blockchain's chain-like structure. A sequential list of blocks is produced. Using the pointer as a hash key, each block in the list refers to its parent block.

Table 1: Pitfalls in Medical Supply Chain Management

Pitfall Category	Description
Fragmentation and Complexity	The medical supply chain involves a complex network of manufacturers, distributors, medical providers, and patients. Managing this fragmented supply chain with diverse stakeholders and processes poses a significant challenge.
Regulatory Compliance	Compliance with regulations is crucial in medical supply chains to ensure patient safety and product quality. Non-compliance can lead to significant legal and financial consequences.
Data Security	Protecting sensitive patient and payment information is paramount in medical supply chains. Robust security measures must be in place to prevent data breaches and ensure compliance with privacy regulations.

Counterfeit Products	The medical industry is vulnerable to counterfeit products, which can present serious risks to patient safety. Implementing measures to detect and prevent counterfeit products is a challenge for supply chain management.
Payment Processing	Managing payments between different entities in the context of the medical supply chain can be complex and time-consuming. Ensuring timely and accurate payment processing while complying with regulatory requirements adds to the challenge.
Refunds and Returns	Handling refunds and returns of healthcare products requires careful coordination between manufacturers, distributors, and medical providers. Managing the reverse logistics process and ensuring proper documentation is challenging.

Every network participant has access to both their public and private keys. The block information or data is signed using the secret key. These blocks that have a digital signature are scattered around the network and are open to all users. There are two steps in the digital signature process: the signing phase and the verification phase. Every node in the blockchain contributes to the verification of block information through the process of consensus determination [11].

Integrating blockchain in Medical Supply Chain Management (MSCM) has shown promise for revolutionizing transparency, dependability, and traceability. Its decentralized architecture ensures transparency and dependability by keeping an immutable, consistent record of all transactions across all network nodes [12]. Scientists and industry leaders looking at blockchain's real-time application in MSCM find it appealing because of these characteristics. Medical supply chains, which involve complex processes ranging from product distribution to raw material extraction, must be properly managed to ensure patient safety [13].

This capability is particularly significant for strictly regulated sectors such as like pharmaceuticals, where product traceability is important for adhering to stringent regulatory standards [6]. Blockchain technology's capability to offer secure data sharing between several sources, according to conditions and goals authorized by patients. Blockchain technology looks to be a workable solution to the problems with the MSCM, which tracks drugs throughout the whole supply chain and offers a comprehensive defense against the proliferation of counterfeit drugs. Despite its numerous potential advantages, there has been limited research conducted on the impact of Blockchain on the sustainability of medical supply chains. [7]. The goal of this study is to look into prospective methods in which blockchain technology could support MSCM sustainability, given the gap in this area and the paucity of blockchain research in this area. By utilizing the potential of blockchain technology, this research seeks to improve MSCM security and efficiency [8].

5 Proposed Blockchain MSCM Model: Enhancing Security and Efficiency

Blockchain, an immutable and decentralized ledger, improves medical supply chain management through enhanced transparency, traceability, and security. It enables real-time product tracking, reduces counterfeiting, and ensures data integrity. The decentralized design of blockchain fosters trust among stakeholders, enhancing efficiency and accountability within supply chain. The suggested blockchain model prioritizes transparency, allowing users to view details about raw material production and composition. It addresses conventional challenges and adds features such as secure payments and refunds to enhance customer satisfaction.

5.1 System Design: The proposed model is founded on blockchain technology and involves four key entities: clients (patients, hospitals, and dispensaries), distributors, manufacturers, and raw material suppliers. It offers a secure payment gateway and provides detailed information about the composition of raw materials, along with a comprehensive list of raw materials. This model aims to enhance transparency and trust within the medical supply chain, ensuring the integrity and safety of medical products and services. Proposed Model consists of 4 types of entities

- **Clients**: Includes hospitals, dispensaries, patients etc. They can purchase medicines from distributors.
- **Distributors**: They can purchase stock from manufacturers. Sell medicines to patients. List available stock.
- **Manufacturers**: They can purchase raw materials from raw material suppliers. Supply stock to distributors.
- **Raw Material Suppliers**: They supply raw materials to manufacturers. They also list raw materials.

Figure 1 illustrates the system design, depicting relationships between entities and user interactions with the application. All entities have secure access to the application through an encrypted access key, ensuring data integrity and confidentiality. This security measure enhances the overall protection of the system. In the application, user interactions are first processed by the user interface, then passed to a smart contract. The smart contract interacts with the blockchain, which communicates with the data storage layer. This process guarantee that all actions are securely recorded and validated, maintaining the integrity of the system.

All entities within the system can access comprehensive information about raw materials, including details on composition, suppliers, and an exhaustive list of available raw materials. This transparency ensures that all involved parties, such as manufacturers and distributors, can make well-informed decisions based on the shared

and up-to-date information regarding the raw materials involved in the production process.

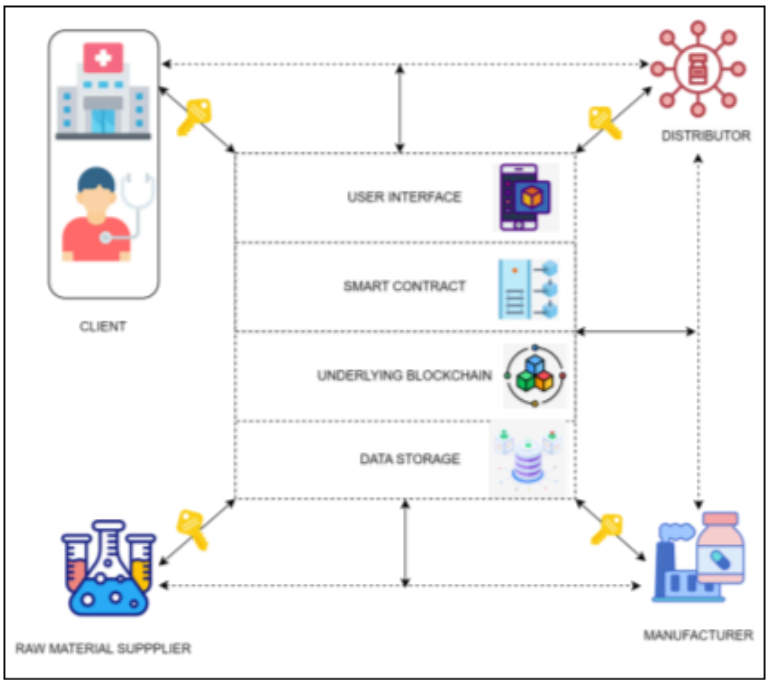

Figure 1: Proposed Blockchain MSCM Model

5.2 Interaction among Entities in the Proposed Model: Upon client placement of a pharmaceutical order via the application, the system forwards the request to the distributor. Post-processing, the distributor issues an acknowledgment (approval or rejection) to the client. For accepted orders, the client proceeds to pay the order price through the application, and the payment is transmitted to the distributor. In situations where stocks are unavailable or the client opts for cancellation, refunds align with the distributor's policy. This seamless process ensures efficient order management.

When the distributor places a pharmaceutical order through the application, the system forwards the request to the manufacturer. Following order processing, the manufacturer issues an acknowledgment (approval or rejection) to the distributor. For accepted orders, the distributor proceeds to pay the order price through the

application, and the payment is transmitted to the manufacturer. In cases of stock unavailability or distributor-initiated cancellations, refunds align with the manufacturer's policy. This streamlined process ensures effective order management, transparent communication, and adherence to refund procedures transparent communication, and adherence to refund procedures.

When the manufacturer places a pharmaceutical order through the application, the system forwards the request to the raw material supplier. Following order processing, the raw material supplier issues an acknowledgment (approval or rejection) to the manufacturer. For accepted orders, the manufacturer proceeds to pay the order price through the application, and the payment is transmitted to the raw material supplier. In cases of stock unavailability or manufacturer-initiated cancellations, refunds align with the raw material supplier's policy. This expedited procedure guarantees efficient supply chain management, transparent communication, and adherence to refund procedures.

5.3 Modules and Processing: Proposed Model has been further divided into three different modules: Client-Distributor Module, Distributor-Manufacturer Module and Raw Material Supplier-Manufacturer Module for mapping, interactions and processing between different entities in the system.

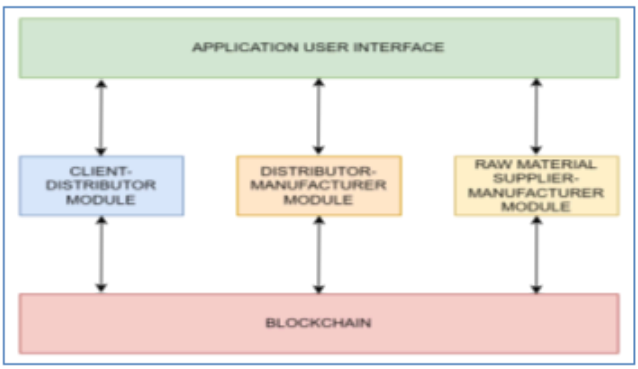

Figure 2: Modules in the Proposed BMSCM Model

Figure 2 depicts modules in the proposed model. Each module play specific role in the supply chain process. The client distributor module handles with clients and distributors, the distributor manufacture model manages activities between distributors and manufacturers, and the raw material supplier, manufacturer module manages activity between raw material supplier and manufacturer. By sending data to

blockchain we are ensuring that the information is secure, transparent and tamper-resistant.

The medical supply chain model is designed to operate through a systematic flow algorithm shown in Figure 3, ensuring the smooth interaction of its key entities. Beginning with patient interaction, the system allows patients to request information about medicines and access details about raw materials and their suppliers. Distributors then purchase stock from manufacturers and list available stock for patient purchase. Manufacturers, in turn, purchase raw materials from suppliers and supply stock to distributors. Raw material suppliers play a crucial role by providing raw materials to manufacturers and listing their available inventory. Throughout this process, authentication and authorization mechanisms are in place to verify user identities and permissions.

Processing Algorithm

```
INPUT: User access id
OUTPUT: Formation of new record on the blockchain.
PROCESSING:
 while True:
      user = authenticateUser() // Verify user credentials

      if user.role == "patient":
         request = patientInteraction() // Patient seeks medication details
         viewRawMaterials(request) // Access information on raw materials
         purchaseMedicineFromDistributor()

      else if user.role == "distributor":
         purchaseStockFromManufacturer() // Distributor buys stock
         listAvailableStock() // Display available stock for sale

      else if user.role == "manufacturer":
         placeOrderForRawMaterials() // Manufacturer orders raw materials
         supplyStockToDistributor() // Manufacturer provides stock to
distributor

      else if user.role == "raw_material_supplier":
         supplyRawMaterialsToManufacturer() // Supplier delivers raw
materials
         listAvailableRawMaterials() // Display available raw materials

     If user.request_Refund:
         processRefund(user) //Process refund if requested
      trackData(user) // Record user activity
```

Figure 3: Processing Algorithm

6 Conclusion

In this research paper, we proposed a supply chain management model in medical care to alleviate the various challenges faced by this critical industry. Our model focuses on enhancing transparency by allowing users to view comprehensive information regarding raw materials, their composition, and the suppliers of these materials. Additionally, we have incorporated a secure payment gateway and a refund mechanism to ensure smooth transactions within the supply chain. By addressing these issues, our model aims to improvise the efficiency and reliability of medical supply chains, ultimately leading to better patient outcomes. Overall, our research contributes to the ongoing efforts to optimize medical supply chains, highlighting the blockchain technology's potential to revolutionize the industry's operations and improve the quality of care delivered to patients.