Industry 4.0 Integration To Supply Chain Of Pharmaceutical Industries

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Bachelor of Technology

by

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(2020MMB1348)

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Declaration of Originality

I hereby declare that the work which is being presented in the report entitled Industry 4.0 Integration To Supply Chain Of Pharmaceutical Industries has been authored by me. It presents the results of my own independent investigation/research conducted during the time period from August 2023 to May 2024 under the supervision of Dr. Khushboo Rakha. To the best of my knowledge, it is an original work, both in terms of research content and narrative, and has not been submitted or accepted elsewhere, in part or in full, for the award of any degree, diploma, fellowship, associateship, or similar title of any university or institution.

Kritik Verma
2020MMB1348

Certificate

This is to certify that the report entitled Industry 4.0 Integration To Supply Chain Of Pharmaceutical Industries, submitted by Kritik Verma (2020MMB1348) in partial fulfillment of the requirements for the award of the degree of 'Bachelor of Technology' of Indian Institute of Technology Ropar, is a record of bonafide research work carried out under my guidance and supervision. To the best of my knowledge and belief, the work presented in this report is original and has not been submitted, either in part or full, for the award of any other degree, diploma, fellowship, associateship or similar title of any university or institution. In my opinion, the report has reached the standard fulfilling the requirements of the regulations relating to the Degree.

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Abstract

Blockchain technology has significance for revolutionizing the pharmaceutical supply chain by enhancing transparency, traceability, and security. In the current system, the pharmaceutical supply chain faces several challenges, including the presence of counterfeit medicines, the inability to track the origins of medicines, and a lack of transparency in the movement of pharmaceutical products.

Counterfeit medicines have a serious threat to public health, as they can contain harmful ingredients or incorrect dosages. With blockchain, each transaction involving pharmaceutical products can be recorded in a secure and immutable ledger, enabling stakeholders to verify the authenticity of medicines at every step of the supply chain. This transparency can help in reducing the circulation of counterfeit medicines in the market.

Moreover, blockchain technology can enable the tracking of pharmaceutical products from the manufacturer to the end consumer. This traceability is important for identifying the source of any issues, such as counterfeit products and taking appropriate action. By providing a complete and transparent record of the journey of each medicine, blockchain can help in ensuring the safety and quality of pharmaceutical products.

Recent developments in the industry have shown a growing interest in using blockchain to enhance supply chain management. For example, some companies have started using blockchain to track food products, ensuring their authenticity and quality. Similarly, blockchain has been used in the construction industry to trace the origins of materials, improving transparency and accountability in the supply chain.

Blockchain technology has the potential to address many of the challenges faced by the pharmaceutical supply chain. By enhancing transparency, traceability, and security, blockchain can help in ensuring the authenticity and quality of medicines, ultimately benefiting public health.

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1. Introduction

Blockchain technology has transformed many industries by offering a secure and clear method to record transactions. In the pharmaceutical field, where the authenticity and reliability of products are crucial, using blockchain in the supply chain can improve traceability and ensure the safety of medicines. Blockchain is a computer system that keeps information safe and makes it easy to see. In this report, we'll talk about how we can use blockchain to help making pharmaceutical supply chain more efficient and reliable for consumer and other stakeholder

1.1 Blockchain: A Secure Information System

In today's digital world, secure and transparent record-keeping is essential. Blockchain technology has emerged as a powerful tool for exactly this purpose. It's a digital system designed to store information in a way that's both secure and easy to track. A chain of blocks, where each block holds a piece of information and is linked to the ones before and after it. Cryptography, a complex coding system, further encrypts this information, making it tamper-proof. This structure allows anyone with permission to see the information on the blockchain, creating a clear and reliable record.

1.2 Importance of Safe Medicines

The safety of medicines data is very important in the pharmaceutical industry. Counterfeit drugs, unfortunately, have a significant threat. These limitations can be ineffective, leading to untreated illnesses or they can cause harmful side effects or even be fatal. To ensure patient safety, a reliable system for tracking medication throughout its journey, from manufacturing to consumption, is crucial.

1.3 Blockchain for a More Efficient Supply Chain

The path a medicine takes from its creation to reaching a patient's hands involves a complex network of people and businesses – this is known as the supply chain. Traditionally, tracking this movement can be slow. Blockchain can revolutionize this process. By creating a shared, digital record of a medicine's movement, everyone involved can see its location and condition in real-time. This not only improves efficiency but also reduces unnecessary paperwork and streamlines overall processes.

1.4 Benefits for Consumers and Stakeholders

Complete confidence in the authenticity and safety of the medication you're taking. Blockchain in the pharmaceutical supply chain offers this very benefit to consumers. By creating a transparent and traceable system, patients can be assured of the medicine's origin and quality. But the advantages extend beyond consumers. Manufacturers, distributors, and regulatory bodies can all benefit from increased transparency, reduced costs through improved efficiency, and faster resolution procedures in case of any issues.

2. Problem Statement

The pharmaceutical industry is important for keeping people healthy. But there are some problems in how medicines are made and delivered. There are four main issues in this supply chain.

2.1 Counterfeit Medications:

Counterfeit drugs in the pharmaceutical supply chain have a significant threat to public health and patient well-being. These limitations can be incredibly dangerous, containing ineffective ingredients or even harmful substances. Here's how counterfeit drugs impact the system:

- **Potential Harm:** Patients taking counterfeit medications may not receive the intended treatment, leading to bad health conditions or ineffective treatment for serious illnesses.

- **Compromised Treatment:** Counterfeit drugs can contain incorrect dosages or even toxic ingredients, causing severe side effects or even fatalities.
- **Decreased Public Trust:** Counterfeit drugs affect public trust in the pharmaceutical industry, discouraging patients from seeking legitimate medication and potentially delaying necessary treatments.

The current system lacks robust methods to prevent counterfeit drugs from entering the supply chain. Traditional tracking methods are often paper-based or rely on centralized databases, making them vulnerable to manipulation.

2.2 Lack of Transparency:

The complex nature of the pharmaceutical supply chain in India suffers from a lack of transparency and real-time visibility. This means:

- **Limited Consumer View:** Consumers have little to no information about the journey their medication takes. They can't track its origin, manufacturing process, or storage conditions, leading to concerns about authenticity and quality.
- **Reduced Efficiency:** Opaque systems create bottlenecks and delays in the supply chain. Difficulty in tracing specific medicines makes it hard to identify and address shortages or product recalls efficiently.
- **Difficulties in Addressing Issues:** Lack of transparency makes it challenging to pinpoint the source of problems like quality concerns or drug shortages. This hinders timely intervention and corrective measures.

2.3 Regulatory Challenges:

Ensuring everyone involved in the pharmaceutical supply chain depends on strict regulations is important for patient safety and drug quality. These regulations cover aspects like:

- **Manufacturing Practices:** Regulations ensure medications are produced in safe and controlled environments to maintain consistent quality and effectiveness.
- **Storage and Distribution:** Proper storage and transportation procedures are crucial to maintain the potency and integrity of medications.

- **Record-Keeping:** Detailed records must be maintained to track the movement of medication throughout the supply chain for traceability and accountability.

However, the current system faces challenges in enforcing regulations:

- **Difficulty in Monitoring:** Traditional paper-based records and fragmented systems make it hard for regulatory bodies to effectively monitor adherence across the entire supply chain.
- **Risk of Non-Compliance:** Loopholes or weaknesses in the system can be exploited by those looking to bypass regulations, potentially compromising drug quality.

2.4 Collaboration Gap:

A well-functioning pharmaceutical supply chain requires collaboration among various stakeholders:

- **Manufacturers:** Responsible for producing high-quality and safe medications.
- **Distributors:** Move medications from manufacturers to pharmacies and hospitals.
- **Regulatory Authorities:** Enforce regulations and ensure medication safety.
- **Healthcare Personnel:** Prescribe and dispense medication to patients.

However, communication gaps and a lack of a unified platform hinder collaboration:

- **Limited Information Sharing:** Information prevents stakeholders from sharing crucial data about production, storage, and distribution, leading to inefficiencies.
- **Difficulty in Coordination:** Unpropper communication makes it challenging to coordinate efforts across the supply chain, impacting timely responses to issues like product recalls.
- **Reduced Accountability:** Difficulty in tracking individual actions within the supply chain makes it harder to pinpoint where issues originate, hindering accountability.

The current pharmaceutical supply chain faces significant challenges that threaten patient safety and system efficiency. Counterfeit drugs pose a major public health risk, potentially containing ineffective or harmful ingredients. Lack of transparency decreases consumer trust and creates inefficiencies in identifying shortages or quality concerns. Difficulty in enforcing regulations

throughout the complex supply chain leaves loopholes for non-compliance and compromised drug quality. Finally, communication gaps between manufacturers, distributors, regulators, and healthcare personnel descresses collaboration and timely responses to issues.

These problems make the necessity of a solution that promotes transparency, traceability, and secure information sharing. Blockchain technology offers the same approach. By creating a secure, shared digital ledger of all transactions within the supply chain, blockchain can track the journey of a medicine from manufacturing to consumption. This allows everyone involved to see critical information about the origin, storage, and movement of medications, fostering trust and accountability. Additionally, blockchain's tamper-proof nature makes it difficult to introduce counterfeit drugs into the system, protecting patients from harmful imitations. Streamlined record-keeping and real-time tracking capabilities can improve efficiency by allowing for faster identification and response to shortages or quality concerns. Furthermore, a blockchain-based system can facilitate collaboration by providing a unified platform for all stakeholders to share information securely, improving coordination and response times. By addressing these critical issues, blockchain has the potential to revolutionize the pharmaceutical supply chain, ensuring patient safety and creating a more efficient and reliable system for delivering life-saving medications.

3. Literature Review And Market Research

There are various methods to address the challenges of counterfeit medications, supply chain visibility, regulatory compliance, and stakeholder collaboration. Traditional methods include implementing track-and-trace systems, employing serialization technologies, and establishing data sharing platforms.

3.1 Traditional methods

3.1.1 Track-and-Trace Systems:

Track-and-trace systems[2] operate like a logistics network specifically designed for medications. A complex web of warehouses, distributors, pharmacies, and hospitals, each equipped with scanning technology.

- **Unique Identification:** Each medication package receives a unique identifier, typically a barcode or a Radio Frequency Identification (RFID) tag. This identifier acts like a fingerprint, allowing for individual tracking throughout the supply chain.
- **Scanning at Every Step:** At each stage of the medication's journey, from manufacturing to final dispensing, the unique identifier is scanned. This generates a detailed electronic record of the medication's movement, including timestamps and locations.
- **Real-Time Visibility:** The collected data is accessible in real-time by authorized stakeholders. A secure online platform where manufacturers, distributors, and regulatory bodies can see the exact location of any medication at any given moment.
- **Identifying Red Flags:** This real-time visibility allows for immediate identification of potential issues. For example, if a medication appears in a location it shouldn't be, such as a pharmacy not authorized to carry it, it could be a sign of diversion or counterfeiting. This triggers investigations and helps prevent potentially harmful medications from reaching patients.

Track-and-trace systems offer several advantages. They controle counterfeiters by making it difficult to introduce fake medications into the supply chain unnoticed. Additionally, they improve patient safety by facilitating targeted product replacements in case of quality issues. These systems also streamline logistics and inventory management for all stakeholders involved.

3.1.2 Serialization Technologies

Serialization technologies[1][2] take a more granular approach to securing the pharmaceutical supply chain. This method focuses on assigning a unique serial number to each individual drug product.

- **Unique Serial Numbers:** Every single pill, vial, or injection device receives its own unique serial number, often encoded in a two-dimensional barcode. This number is permanently linked to the specific medication and cannot be replicated.
- **Verification at the Point of Sale:** Pharmacies and hospitals are equipped with barcode scanners that can verify the authenticity of the medication before dispensing it to patients. When a barcode is scanned, the system checks the serial number against a central database to confirm its legitimacy.
- **Targeted Recalls and Investigations:** In the event of a product recall or adverse event, serialization allows for targeted action. Regulatory bodies can identify and isolate specific batches of medication with known issues, minimizing disruption and protecting public health. In a situation where a specific batch of medication is found to be defective. Serialization allows authorities to pinpoint exactly which pharmacies and hospitals received that batch, ensuring only those specific medications are removed from shelves.

Serialization technologies significantly reduce the risk of counterfeit drugs entering the supply chain and ensure patients receive genuine medications. Additionally, they provide valuable data for investigations and targeted product recalls.

3.1.3 Data Sharing Platforms:

Data sharing platforms[1][2] act as a secure communication hub for all stakeholders involved in the pharmaceutical supply chain. It is a central platform where manufacturers, distributors, pharmacies, regulatory bodies, and even healthcare providers can access and share critical information.

- **Secure Information Exchange:** The platform provides a secure environment for authorized users to exchange real-time data on medication movement, regulatory requirements, and potential issues. This includes data on inventory levels, shipment details, and potential counterfeit activity.
- **Enhanced Collaboration:** By facilitating communication and collaboration, these platforms allow stakeholders to identify and address problems more effectively. For instance, a distributor noticing a sudden surge in orders for a particular medication in a specific region can share this information with regulatory bodies and pharmacies, enabling investigations into potential counterfeiting.
- **Improved Regulatory Compliance:** Data sharing platforms can significantly ease the burden of regulatory compliance for manufacturers and distributors. By providing a central repository for documentation and data related to product movement and quality control, these platforms streamline the compliance process for all parties involved.

The advantages of data sharing platforms are clear. They improve communication and collaboration across the pharmaceutical supply chain, leading to a more secure and efficient system. Additionally, they help ensure regulatory compliance and ultimately contribute to patient safety.

While these traditional methods offer substantial benefits, it's important to acknowledge their limitations. They can be complex to implement and maintain, requiring significant investments in technology and infrastructure. Additionally, scalability can be a challenge, particularly for smaller players in the pharmaceutical supply chain.

3.2 About Blockchain

Blockchain technology has emerged as a revolutionary approach to data management, offering a secure and transparent method for recording and verifying transactions across a decentralized network. Unlike traditional databases controlled by a single entity, blockchain distributes information across a network of computers, creating a shared ledger accessible to all authorized participants. This eliminates the need for a central authority, fostering trust and accountability within the system.

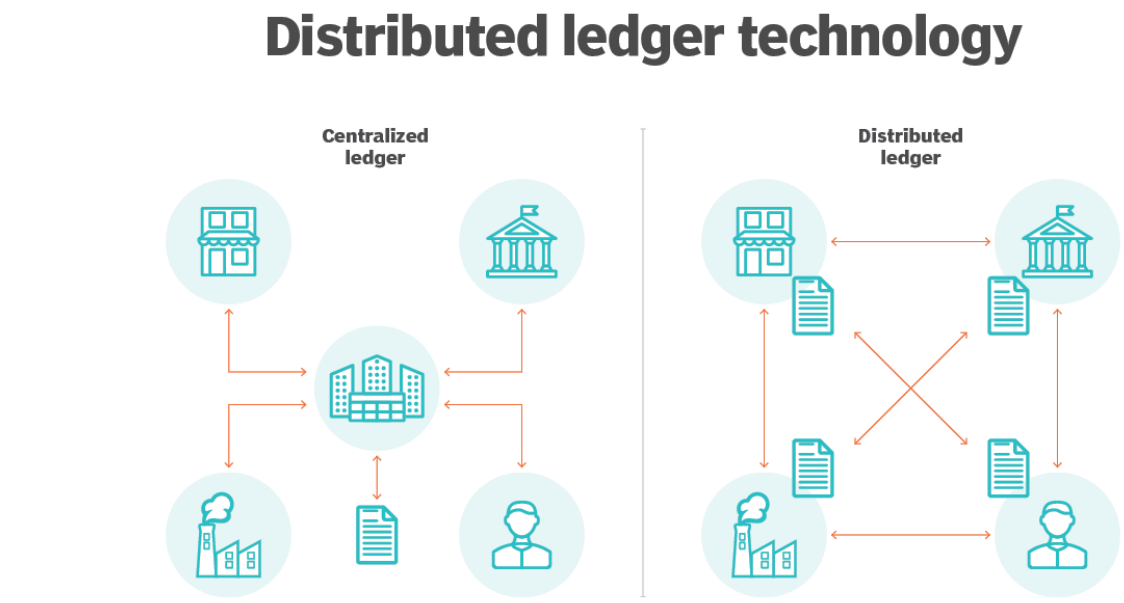

Fig 1 : Distributed ledger

Centralized Ledger:

- In a centralized ledger system, there is a single authority or entity that controls and maintains the ledger. Imagine a record book kept by a single person or organization, like a bank or government agency.
- This central authority is responsible for adding, updating, and deleting information in the ledger.
- Traditional databases are examples of centralized ledgers.

Distributed Ledger:

- A distributed ledger, also known as blockchain technology, distributes the ledger across a network of computers. There is no single point of control.
- Each participant in the network has a copy of the ledger, and any changes made to the ledger must be verified by a majority of the participants before being added.
- This decentralized approach makes it tamper-proof, as altering information on the ledger would require modifying all copies across the network, which is highly improbable.

A giant digital record book, constantly being updated and replicated across numerous computers. Every transaction added to this book is verified and cryptographically linked to the previous entry, forming a chronological chain of tamper-proof data blocks. This "chain" structure makes altering past information incredibly difficult, as any modification would require altering all subsequent blocks across the entire network, a near-impossible feat.

Furthermore, blockchain technology[1] has transparency. Every transaction recorded on the blockchain is visible to authorized participants, fostering a sense of trust and accountability. This real-time visibility makes it impossible to alter data, as any attempt to manipulate data would be readily apparent to all network users.

The decentralized and transparent nature of blockchain technology holds high potential for transforming various industries, particularly those having issues of trust, security, and data security. In the context of the pharmaceutical supply chain, for instance, blockchain can be a game-changer. By creating a secure and transparent record of medication movement from manufacturing to dispensing, it can significantly reduce the risk of counterfeit drugs entering the system. Every step of the journey, from production to distribution and final sale, can be documented and verified on the blockchain[3], providing stakeholders with a clear picture of the medication's authenticity and origin. This not only enhances patient safety but also streamlines logistics and inventory management for all parties involved.

The potential applications of blockchain technology extend far beyond the pharmaceutical industry. It can revolutionize sectors like finance by enabling secure and efficient cross-border transactions. In the voting, blockchain can increase trust and transparency by creating an immutable record of votes, reducing the risk of electoral fraud. Furthermore, it can empower individuals by providing a secure platform for managing personal data and digital identities.

However, it's important to acknowledge that blockchain technology is still in its early stages of development. Scalability remains a challenge, as processing large volumes of data across a decentralized network can be resource-intensive. Additionally, regulatory frameworks need to evolve to accommodate this disruptive technology. Despite these challenges, the potential benefits of blockchain are undeniable. As the technology continues to mature and gain wider adoption, it has the potential to fundamentally reshape how we record, verify, and share information across a multitude of industries.

3.3 How Blockchain is solving these problems

Blockchain technology has the potential to revolutionize the pharmaceutical supply chain by offering several key benefits:

1. **Enhanced Traceability:** Unlike traditional methods, blockchain creates an immutable and decentralized record of a medication's journey from manufacturing to dispensing. Imagine a medication with a digital passport that tracks its movement at every stage. This allows stakeholders to pinpoint the exact location of a medication at any given time, significantly improving traceability throughout the supply chain.
2. **Transparency Throughout the Supply Chain:** All transactions on the blockchain are visible to authorized participants. This transparency fosters trust and accountability among all parties involved. It's like a shared document where everyone can see the movement of medications, from production to distribution, making it difficult to introduce counterfeit drugs or divert medications.
3. **Improved Efficiency and Response Time:** Real-time tracking of medication movement on the blockchain enables stakeholders to coordinate more efficiently. Imagine a system where everyone involved in the supply chain has instant access to information about medication location and inventory levels. This allows for faster responses to disruptions or potential shortages.
4. **Enhanced Data Security and Privacy:** Blockchain utilizes strong cryptographic encryption to secure sensitive data on the network. This includes patient information, clinical trial results, and other confidential data. This encryption protects sensitive data from unauthorized access or tampering.
5. **Verification of Drug Authenticity:** By providing a tamper-proof record of a medication's origin and movement, blockchain empowers stakeholders to verify the authenticity of drugs at any point in the supply chain. This helps to prevent the circulation of counterfeit drugs and protects patient safety[7].

Blockchain technology offers a comprehensive solution for addressing the challenges faced by the pharmaceutical supply chain. By enhancing traceability, transparency, data security, and real-time coordination, blockchain can contribute to a more secure, efficient, and trustworthy system for delivering critical medications to patients[3].

3.4 Current Advancements in Industry

The convergence of blockchain technology and supply chain management is leading to exciting real-world applications across various industries. Here's a closer look at some recent developments:

3.4.1 Construction Industry

Leading Chinese real estate developer Evergrande has partnered with VeChain[4] to leverage blockchain technology. To develop a more transparent and efficient system for managing construction materials. By recording this information on a blockchain, all authorized participants can see the origin, movement, and quality of materials used, fostering trust and accountability throughout the project lifecycle.

3.4.2 Food and Grocery Sector

A collaborative effort by IBM and Reliance Industries[4] in the food and grocery sector demonstrates the power of blockchain. They've joined forces to develop a solution that tracks food products from farm to consumer. This blockchain-powered system aims to establish complete traceability and transparency across the entire supply chain. It allows consumers to scan a barcode and see exactly where their food came from. This level of transparency empowers consumers to make informed choices about the food they eat, while also enabling stakeholders in the supply chain to optimize logistics, minimize food waste, and ensure timely deliveries.

3.4.3 Standardizing Blockchain implementation in Supply Chains

The World Economic Forum, a renowned international organization, has recognized the potential of blockchain technology in supply chain management. They've launched a dedicated initiative to promote its adoption across various industries. The initiative focuses on developing standardized protocols and best practices for using blockchain in supply chains. This will help ensure compatibility and smooth integration of blockchain technology across different sectors, accelerating its widespread adoption.

3.4.3 Indian Government Introducing Blockchain

The Indian government is actively exploring the potential of blockchain technology. Recognizing its ability to enhance security and transparency, they're promoting its adoption in various sectors, including healthcare and elections. Imagine medical records securely stored on a blockchain, accessible only to authorized personnel. This would significantly improve data security and patient privacy. Similarly, blockchain could be used to create a tamper-proof voting system, increasing trust and confidence in the electoral process.

In August 2022, NITI Aayog[5][6], announced a partnership with Oracle, Apollo Hospitals, and Strides Pharma Sciences to pilot a real-time drug supply chain using blockchain technology and IoT software. This project aimed to revolutionize the pharmaceutical supply chain by enhancing traceability, transparency, and efficiency.

These examples highlight the transformative potential of blockchain technology in supply chain management across diverse industries. As the technology matures and gains wider adoption, we can expect even more innovative applications to emerge, fostering a more secure, transparent, and efficient global economy.

4. Implementation

To make a supply chain management system we first have to understand the different parts of the supply chain in medical industries.

Fig 2 : Elements of Supply Chain

4.1 5 Parts of the supply chain.

4.1.1 Factory Level

The process begins at the production facility. Here, a suite of specialized tools (APIs) are integrated with a decentralized blockchain network.

These APIs automatically capture and record crucial data for each individual medication package, including any sub-packages it may contain. This data can include details about the packaging itself, the type of medication, and for temperature-sensitive medications, information about temperature and humidity during storage.

By capturing this data at the outset, the system establishes a detailed record of each medication's journey from the very beginning.

4.1.2 Super Stockist and Warehouse

The medication then moves to a super stockist or warehouse for further distribution. At this stage, a dedicated user interface (UI) application is used to facilitate the receiving process. A warehouse worker can use a computer program to scan barcodes and record the arrival of medication packages.

When a package is opened, revealing its individual subunits (smaller containers within the main package), the system automatically creates a new block on the blockchain. This new block captures both the original package's data and the unique information associated with each subunit.

Essentially, the system creates a detailed log of how the original package is broken down and distributed.

4.1.3. Tracking Through the Supply Chain

The medication then progresses through additional stages of the supply chain, potentially involving further distribution centers or wholesalers.

Throughout these stages, the core functionality remains the same each transfer of medication is documented on the blockchain, ensuring a continuous and transparent record of the medication's movement.

4.1.4 Delivery and Consumer Access

Finally, the medication reaches the consumer. At this point, consumers can utilize a mobile application to access comprehensive data about their specific medication package.

This application allows them to trace the medication's entire journey, from its initial production at the factory to its arrival at their doorstep. The app provides all relevant information about the medication, fostering complete transparency and traceability for the consumer.

This system, powered by blockchain technology, offers a comprehensive solution for tracking medications throughout the supply chain. By capturing detailed data at each stage and providing consumers with access to this information, the system promotes transparency, accountability, and ultimately, patient safety.

4.2 Implementation high level flowchart

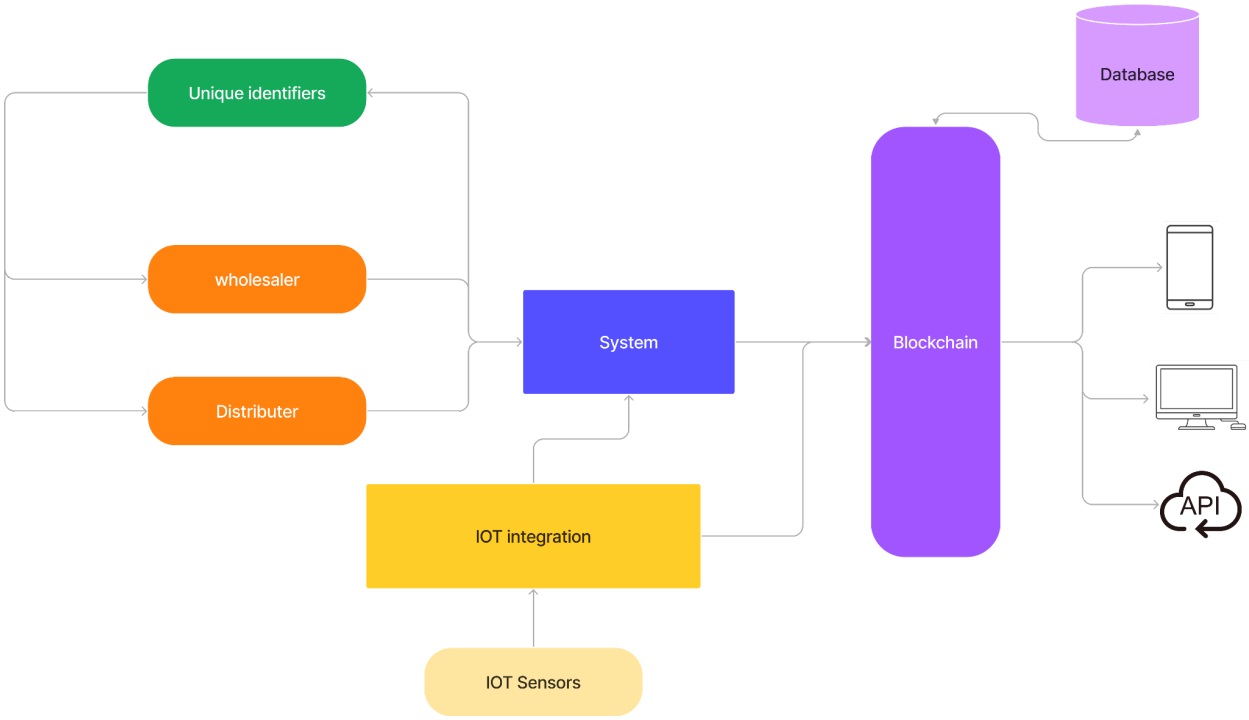

Fig 3 : High Level Implementation

Above is the application architecture[7] diagram for the whole flow of working of the system.

1. **Secure Connection to the Blockchain:** The system connects to a secure blockchain network, which acts as a shared record-keeping system. Imagine a giant digital ledger that tracks all the medication data throughout the supply chain. This connection is likely protected with special digital signatures (violet in the image) to ensure the authenticity and security of the data being recorded on the blockchain.

2. **Growing Data as Packages Divide:** As medication packages move through the supply chain, they may be divided into smaller units at different stages. For instance, a large box of medication might be broken down into individual prescriptions at a distribution center. The blockchain ledger is designed to accommodate this process. Each time a package is divided, a new block is created on the blockchain to reflect the new configuration of medication units.

3. **Web Application for Data Input:** A web application is directly linked to the blockchain at the root level. This web application provides a user interface (UI) for authorized personnel to update data on the blockchain. It is a secure computer program that allows authorized users to input information about the medication, such as the quantity, type, and batch number. This initial data entry populates the root block of the blockchain.

4. **Sensor Data Integration via APIs:** A suite of APIs is used to integrate data from Internet of Things (IoT) sensors directly into the blockchain. IoT sensors can be small devices attached to medication packages that monitor environmental conditions, such as temperature or humidity. The APIs act as intermediaries, allowing the sensor data to be seamlessly transmitted and recorded on the blockchain. Imagine a translator that converts the data collected by the sensors into a format that can be stored securely on the blockchain ledger.

At root level we will have a blockchain which is directly connected to a web application which gives UI to update data on blockchain then we will have a suit of apis which directly push data of IOT sensor into the blockchain

4.3 Technical Stack:

4.3.1 Blockchain Platform:

Ethereum: This is the chosen platform for the underlying blockchain network. Ethereum is a popular blockchain technology known for its ability to support smart contracts, which are self-executing programs that automate specific tasks on the blockchain. In this system, smart contracts could potentially be used to manage medication data updates based on predefined rules.

4.3.2 Smart Contract Development:

Solidity or GoLang: These are programming languages used to develop smart contracts for the Ethereum blockchain. The specific language chosen will depend on developer expertise and the desired functionalities of the smart contracts.

4.3.3 Communication Protocols:

HTTP/HTTPS: These are standard protocols used for communication between different parts of the system. HTTP allows for data transfer over the internet, while HTTPS adds an extra layer of security with encryption.

WebSocket: This is another communication protocol that enables real-time data exchange between the system and web applications. Think of it as a live chat feature that allows for continuous data updates.

4.3.4 IoT Sensor Technology

Temperature, Humidity, GPS, Light Sensors: These sensors are used to collect environmental data related to medication storage and transportation. Imagine tiny devices attached to medication packages that constantly monitor temperature, humidity, location and light exposure. This data is crucial for certain medications that require specific storage conditions.

4.3.5 Barcode Scanning

Mobile Device with Barcode Scanning Capabilities: Standard mobile devices equipped with barcode scanners are used to capture information from medication packaging. Imagine using your smartphone camera to scan a barcode on a medication box, automatically inputting data into the system.

4.3.6 Database Management:

PostgreSQL or MongoDB: These are powerful database management systems that can be used to store additional data related to the medication, such as product descriptions, manufacturing details, and potentially even patient information. The choice between PostgreSQL and MongoDB depends on specific data storage needs and query requirements.

5. Results and Discussion

5.1 User Interface

User Interface (UI) for an application that uses blockchain technology to track medication movement throughout the supply chain. This system promotes transparency, accountability, and ultimately, patient safety. The following sections will delve into the various UI screens designed to provide a user-friendly experience for different participants within the medication supply chain.

5.1.1 Login Screen

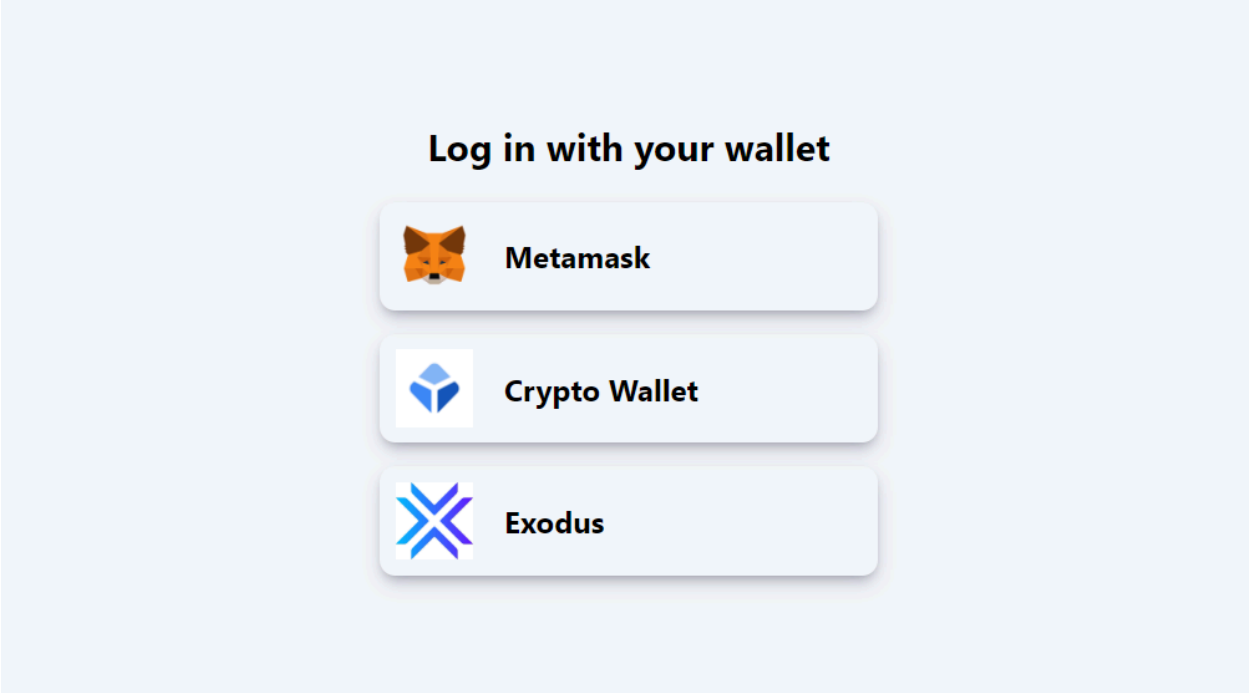

Fig 4 : Login Page

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Login Process:

- **User Input:** The user enters their registered username and password in the designated fields.
- **Credential Verification:** Upon clicking the "Metamask" button, the application transmits the entered credentials to its secure server for verification.
- **Metamask Authentication:** Metamask checks the username and password against its private key of registered users.
- **Login Success/Failure:**
    - **Success:** If the credentials match a valid user account, the server sends an authorization token back to the application. The application then grants access to the user interface based on their permissions within the system.

- **Failure:** If the username or password is incorrect, the server sends an error message back to the application. The application displays an error message on the login screen, prompting the user to re-enter their credentials.

5.1.2 Dashboard

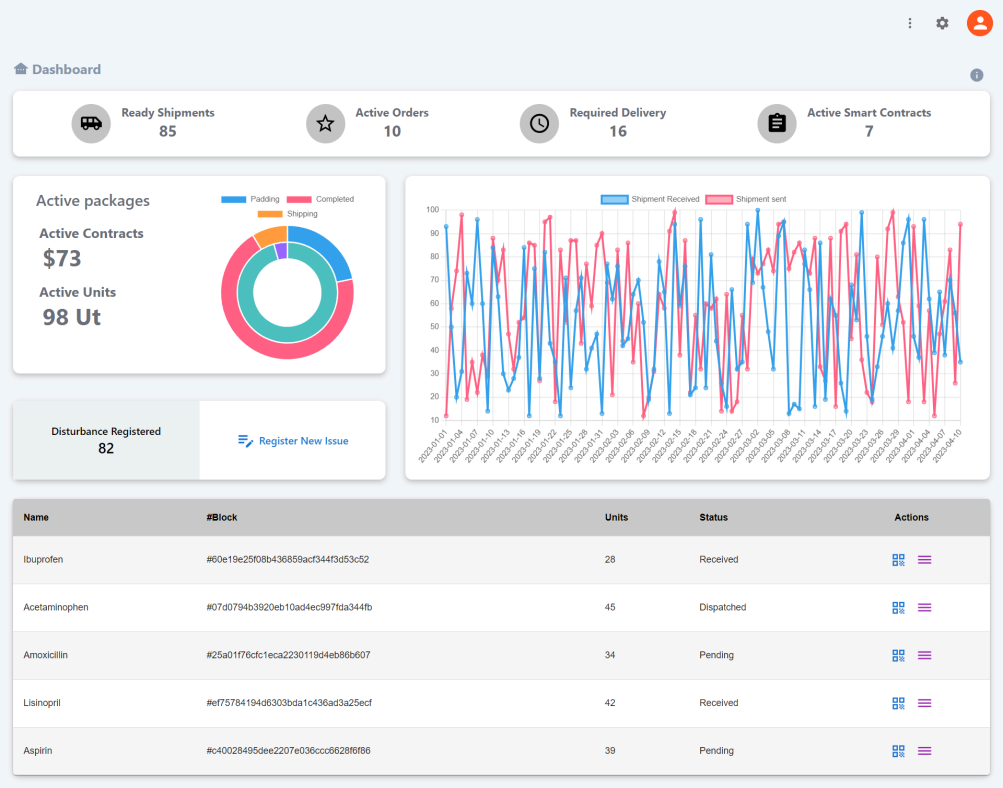

Fig 5 : Dashboard

The distributor dashboard within the medication tracking application serves as a central hub for monitoring active shipments, smart contract interactions, and other crucial data related to inventory management. Here's a breakdown of the potential information and functionalities accessible through this dashboard:

1. Active Shipments:

This section provides a real-time view of all medication shipments currently under the distributor's responsibility. It displays details like origin, destination, shipment ID, medication type, quantity, and estimated delivery time.

2. Active Smart Contracts:

Smart contracts are self-executing programs stored on the blockchain. In the context of this application, they automate specific tasks related to medication movement, such as triggering notifications upon shipment arrival or ensuring certain criteria are met before releasing medication from storage. This section of the dashboard displays information about currently active smart contracts associated with the distributor's shipments.

3. Blockchain Data:

Since the application uses blockchain technology, the dashboard provides access to relevant blockchain data related to the distributor's operations. This includes records of past shipments, transaction logs, and other data stored on the blockchain.

4. Inventory Management:

Efficient inventory management is crucial for distributors. The dashboard offers functionalities to track medication stock levels at various locations within the distributor's network.

5.1.3 Shipment Details

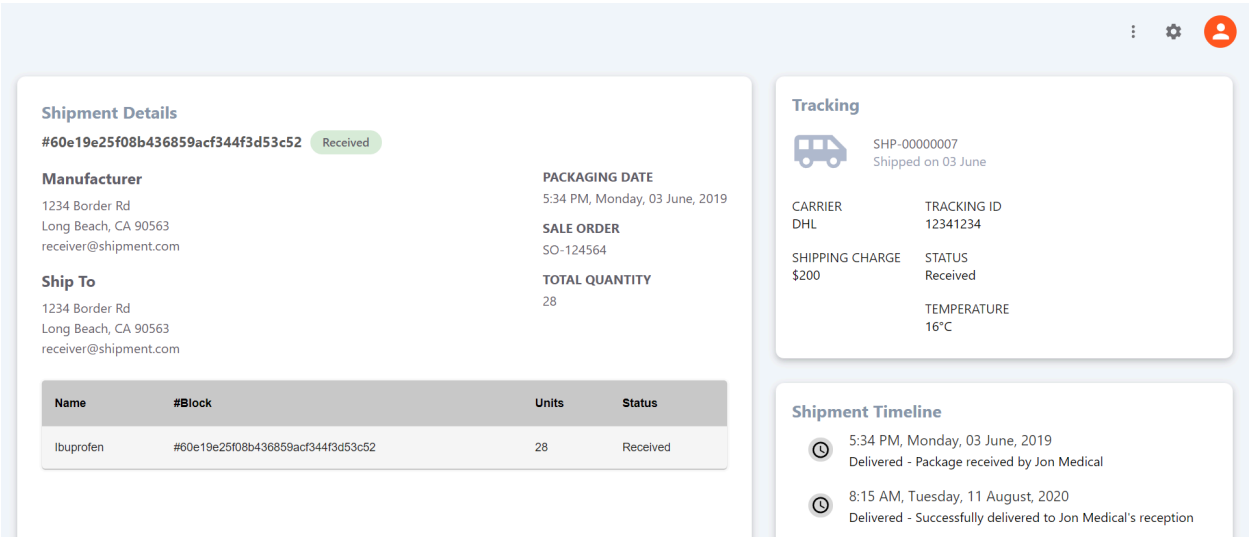

Fig 6 : Shipment Details

Above visual representation of a block on the blockchain network used by this application shows each block as a secure digital container that stores information about a specific shipment for the distributor. Here's a breakdown of the elements.

1. Block Header:

This section acts like a label for the block, containing essential information for identification and linking within the blockchain chain. It include:

- **Block Hash:** A unique digital fingerprint for this specific block, ensuring its data integrity.
- **Previous Block Hash:** A reference to the hash of the block that came before it in the chain, creating a chronological link between blocks.
- **Timestamp:** Recording the exact date and time the block was created.

2. Shipment Data:

This is the core content of the block, containing detailed information about the specific medication shipment for the distributor. It included:

- **Distributor ID:** Identifying the distributor responsible for the shipment.
- **Shipment ID:** A unique identifier for this specific shipment.
- **Origin and Destination:** Locations where the shipment originates from and is headed to.
- **Medication Details:** Type, quantity, and batch numbers associated with the medication.
- **Temperature and Humidity Data**: For temperature-sensitive medications, sensor data recording storage and transportation conditions.

5.1.4 Create Transaction

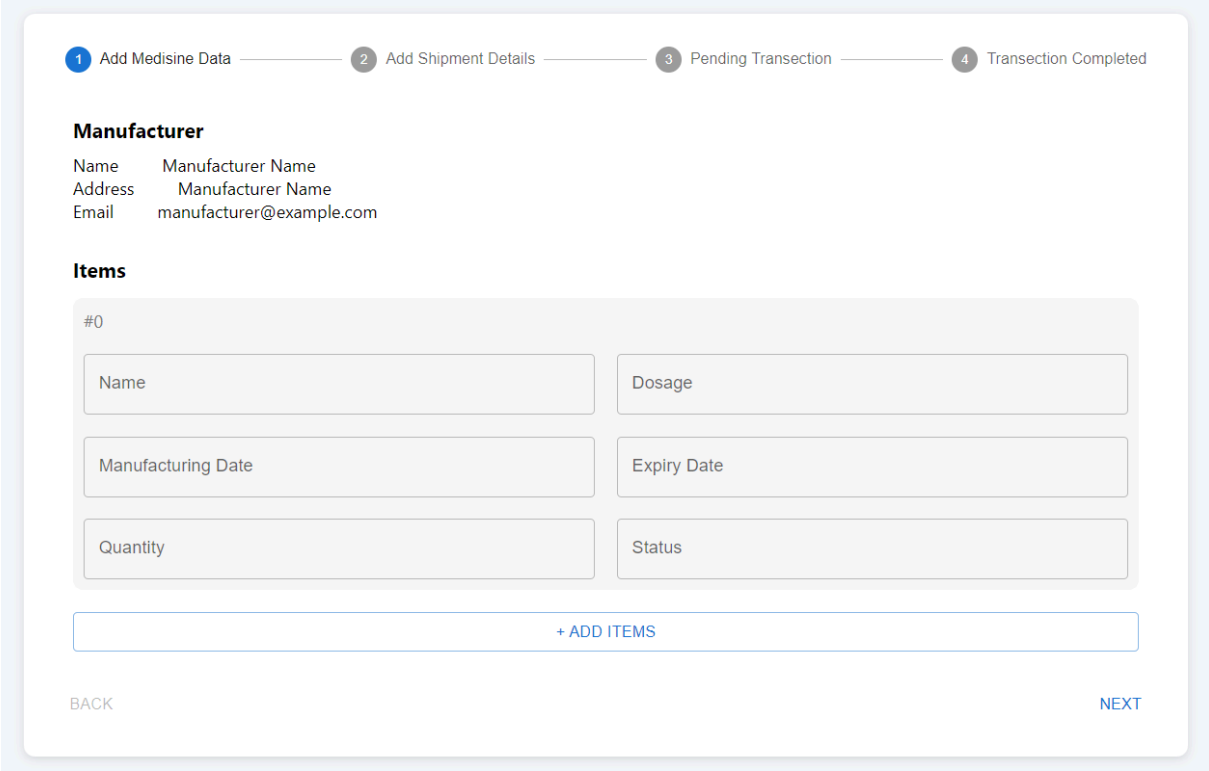

Fig 7a : Create Transaction

Process of creating a new shipment on this application includes following four steps:

Step 1: Manufacturer Details (Fig 7a)

This initial stage includes information about the manufacturer responsible for the shipment.

- **Manufacturer Name:** The name of the company that produced the medication.
- **Manufacturer Address:** The physical location of the manufacturing facility.
- **Manufacturer Email:** A contact email address for the manufacturer.

Step 2: Adding Medication Details (Fig 7a)

This section contains the medications information in the shipment.

Think it includes a list where you have to add individual medication entries. You have an "Add Item" button to include multiple medications within the same shipment. For each medication, you have to enter details:

- **Medicine Name**: The brand or generic name of the medication.
- **Dosage:** The amount of medication in each unit (e.g., milligrams, milliliters).
- **Manufacturing Date:** The date the medication was produced.
- **Expiry Date:** The date by which the medication should no longer be used.
- **Quantity:** The number of units of each medication being shipped.
- **Status:** The current status of the medication within the shipment (e.g., "Packaged", "Ready for Dispatch").

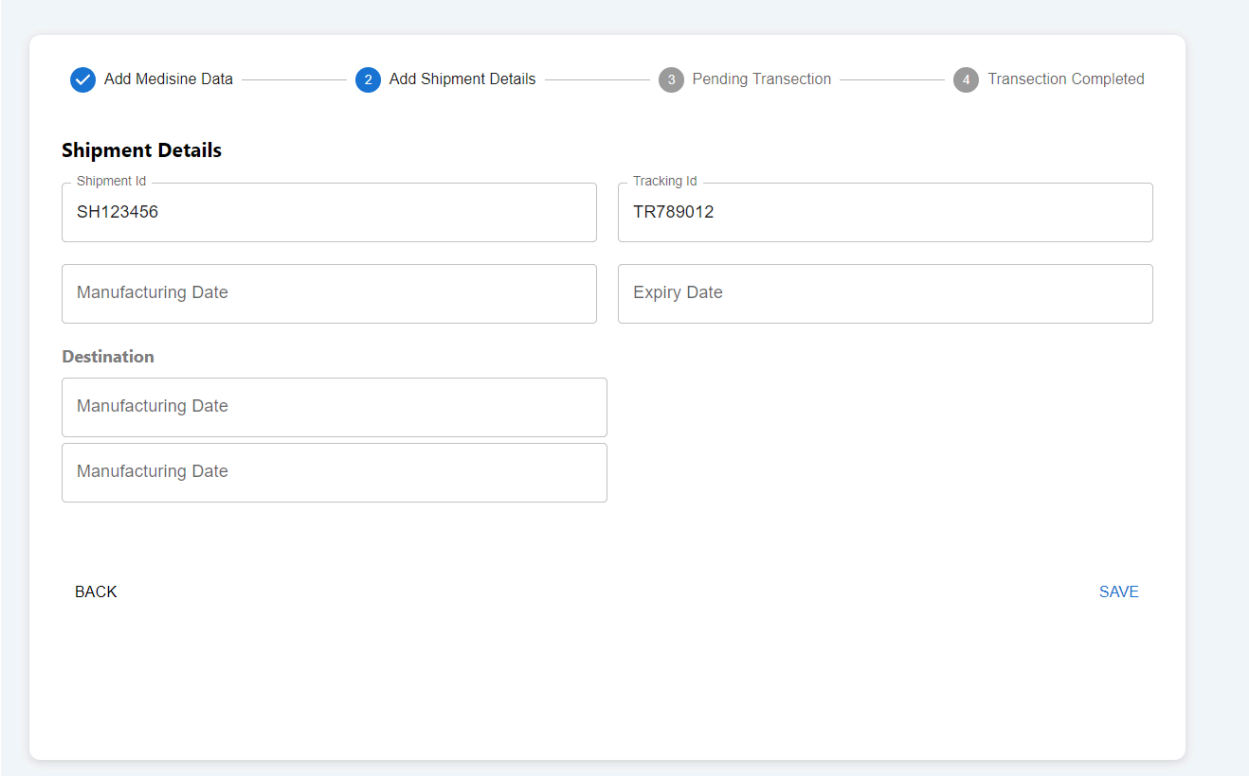

Fig 7b : Transaction Shipment Details

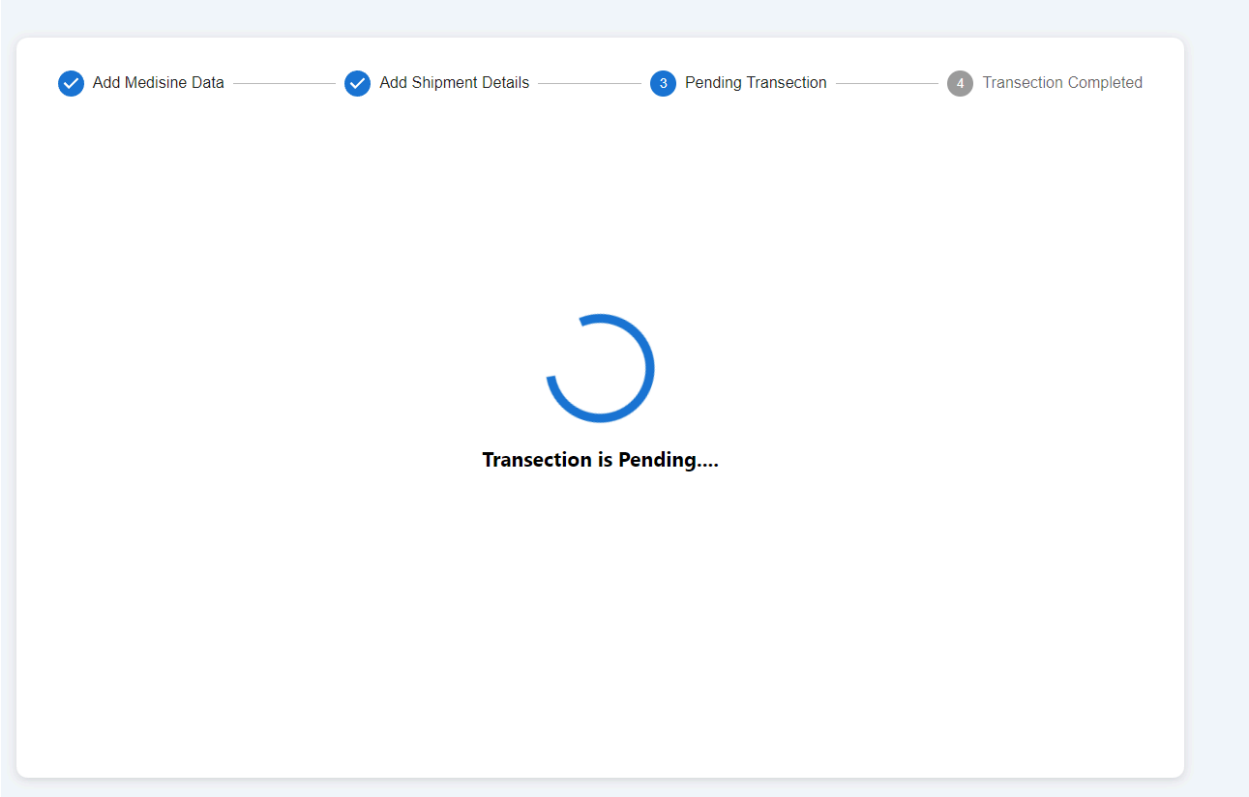

Fig 7c : Transaction Validation

Step 3: Shipment Details and Verification (Fig 7b & Fig 7c)

This stage includes shipment details and initiating the data transfer to the blockchain network.

- **Shipment ID:** This field might be automatically generated by the system to provide a unique identifier for the shipment.
- **Tracking ID:** Another system-generated identifier that allows for real-time tracking of the shipment throughout the supply chain.
- **Expiry Date**: The overall expiry date for the entire shipment, considering the expiry dates of individual medications.
- **Shipment Address:** The destination where the shipment will be delivered.

Once you confirm the details, the system will initiate a verification process (Fig 7c). A loader icon indicating that the application is validating the information and preparing to send it to the blockchain network.

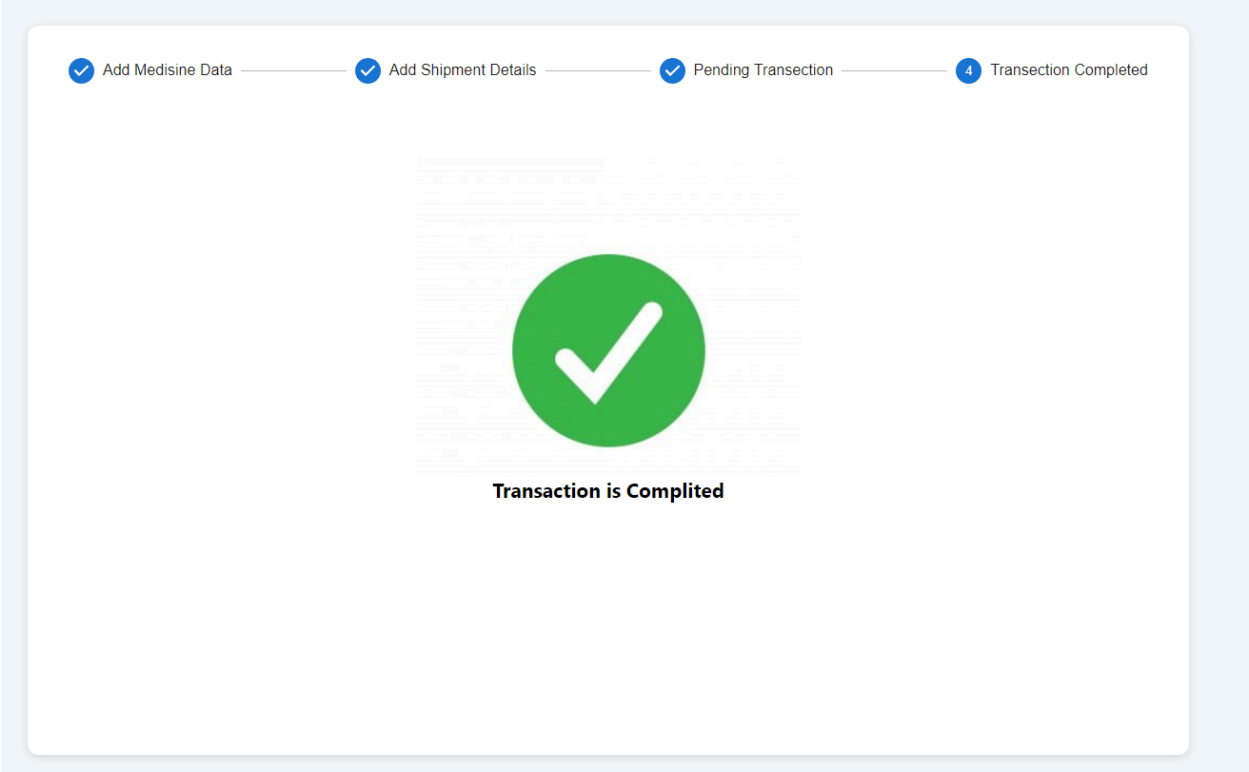

Fig 7b : Verification Success

Step 4: Confirmation and Success (Fig 7d)

After successful verification and data transfer to the blockchain, you will see a confirmation screen (Fig 7d). This screen displays a success message and a visual indicator to confirm that the shipment details have been successfully recorded on the blockchain.

The proposed blockchain-based system has the potential to improve the tracking and management of medical packages throughout the supply chain. By using blockchain technology, IoT sensors, and barcode scanning, the system can provide real-time visibility into the movement and status of packages, ensuring the integrity and safety of medical products.

While the proposed system offers significant benefits, it is important to consider potential challenges and limitations:

- **Technical Complexity:** Implementing and maintaining a blockchain-based system requires specialized expertise and resources.

- **Adoption and Integration:** Widespread adoption of the system across the pharmaceutical supply chain will require collaborative efforts and integration with existing infrastructure.

Despite these challenges, the benefits of blockchain-based tracking systems for medical packages are very significant. As blockchain technology continues to mature and gain wider acceptance, we can expect to see increased adoption of such systems, ultimately improving the efficiency, transparency, and safety of the pharmaceutical supply chain.

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Appendix

1. All the code related to the application can be found on https://github.com/vermaKritik/btp