A Project Report On

DETECTION OF COUNTERFEIT MEDICAL PRODUCTS

Submitted in partial fulfillment of the requirement for the 8th semester

Bachelor of Engineering

in

Computer Science and Engineering

DAYANANDA SAGAR COLLEGE OF ENGINEERING

(An Autonomous Institute affiliated to VTU, Belagavi, Approved by AICTE & ISO 9001:2008 Certified)

Accredited by National Assessment & Accreditation Council (NAAC) with 'A' grade

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CERTIFICATE

This is to certify that the project entitled**Detection of Counterfeit Medical Products** is a bonafide work carried out by **Rachana.L [1DS19CS122]**, **Ranjita Naik [1DS19CS125], Rashmika Satish [1DS19CS126]** and **Saba Naseem [1DS19CS136]** in partial fulfillment of 8th semester, Bachelor of Engineering in Computer Science and Engineering under Visvesvaraya Technological University, Belgaum during the year 2022-23.

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Abstract

Supply networks in the healthcare sector are essential for ensuring the accessibility of real medicinal products. Inaccurate information, a lack of transparency, and the ubiquitous problem of counterfeit goods, which pose serious threats to the general public's health and result in huge financial losses, are some of the difficulties that these supply chains frequently deal with. According to estimates, up to 30 percent of medical products offered in underdeveloped nations are fake. The installation of a decentralised blockchain system created expressly for medical product traceability and regulation is suggested in this report as a solution to these problems. By utilising Ethereum blockchain technology, manufacturers may offer genuine goods while lowering the requirement for directly controlled storefronts and the related costs of product quality assurance. The blockchain approach presented here improves openness and data provenance across the healthcare supply chain, in contrast to conventional techniques that rely primarily on manufacturer confidence and lack real-time tracking. A trustless environment is created and immutable transaction records are guaranteed by doing away with the need for a central authority.The proposed approach gives customers the ability to independently confirm the legitimacy of medical supplies thanks to an intuitive web interface that allows for real-time product verification and tracking via scanned QR codes. The solution also lessens the risk of data manipulation because to its reliable blockchain data storing architecture. This method offers considerable advantages, such as greater consumer safety, improved supply chain transparency, and lower costs for producers by utilising blockchain technology in the fight against fake medical items.

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List of Abbreviations

RFID Radio Frequency Identification 3

EPC Electronic Product Code 3

GS1 Global Standards 1 3

QR Quick Response 4

FDA Food and Drug Administration 4

WHO World Health Organization 8

WSN Wireless Sensor Network 8

CP-ABE Cyphertest Policy Attribute Based Encryption 9

GDSN Global Data Syncronization Network 9

NFC Near Field Communication 10

POD Proof of Delivery 11

POA Proof of Authority 11

DPOS Delegated Proof of Stake 11

POW Proof of Work 11

POS Proof of Stake 11

UTXO Unspent Transaction Output 11

DApps Decentralized Applications 13

IPFS Interplanetary File System 13

AWS S3 Amazon Simple Storage Service 14

PKI Public Key Infrastructure 14

API Application Programming Interface 14

CRC-32 Cyclic Redundancy Checksum 14

NEM New Economy Movement 14

75 **MSP** Membership Service Provider 15

PBFT Practical Byzantine Fault Tolerance 15

CSC Construction Supply Chain 15

MITM Man in the Middle 31

Chapter 1

Introduction

1.1 The problem

The primary challenge we encounter is the prevalence of counterfeit medical products within healthcare supply chains. The complexity of these supply chains, coupled with limitations such as inaccurate information, lack of transparency, and limited data provenance, allows counterfeit products to infiltrate the system. This not only poses serious risks to public health but also leads to significant economic losses for the pharmaceutical industry. The problem is further exacerbated in developing countries, where up to 30 percent of medical products are reported to be counterfeit, resulting in a substantial threat to human lives, particularly among children.

1.2 Real World Application

This application, which focuses on enhancing traceability and combating counterfeit medical products using blockchain technology, can find utility across various domains within the healthcare industry. Some of the potential domains where this application can be deployed include:

1. Pharmaceutical Manufacturing: The application can be implemented by pharmaceutical manufacturers to ensure the authenticity of their products throughout the production and distribution processes.

2. Supply Chain Management: The application can be integrated into the overall supply chain management systems of healthcare organizations. By leveraging blockchain for traceability, it enables transparent tracking of products from the point of origin to the end consumer, ensuring the authenticity and quality of medical products along the entire supply chain.

3. Hospital and Clinical Settings: Hospitals and clinics can utilize the application to verify the authenticity of medications and medical devices used in patient care. This helps prevent the use of counterfeit products and ensures the safety and effectiveness of treatments.

4. Online Pharmacies and E-commerce Platforms: The application can be integrated into online pharmacies and e-commerce platforms to provide assurance to customers regarding the authenticity of the medical products they purchase. It enables consumers to verify the legitimacy of products before making a purchase, enhancing trust and safety in online transactions.

1.3 Organization of the Project Report

In Chapter (2) we discuss the problem statement and the proposed solution. We also take a look at the systems that exist today and the drawbacks they face.

Chapter (3) takes a more in-depth look at various non-blockchain and blockchain based solutions that exist, with a survey on existing literature available.

Chapter (4) looks at the architecture of the proposed solution with an overview of the system design, utilizing system block diagrams and data flow diagrams.

Chapter (5) dives into the Implementation of the solution, by describing the hardware and software requirements, along with implementation details.

Chapter (6) dives into the results and the discussion where the security analysis and the limitations of the project is discussed.

Chapter (7) includes the conclusion and the future enhancements.

Chapter 2

Problem Statement and Proposed Solution

2.1 Problem Statement

To detect the counterfeit medical products within complex healthcare supply chains.

2.2 Existing Systems

The below figure 2.1 explains traditional healthcare supply chain with stakeholders.Traditional supply chain services have traditionally utilized barcode technology, Radio Frequency Identification (RFID) and Electronic Product Code (EPC) to track and manage goods as they move through the supply chain. These technologies allow for the capture and communication of product data, including unique serial numbers, production dates, and expiration dates, using Global Standards 1 (GS1) standards barcodes. RFID tags, while scalable and capable of storing data, can be expensive to implement and may not function properly in cases where radio frequency waves collide or are obstructed.The use of a Data-Matrix monitoring system further enhances traceability by creating a Data-Matrix for each drug, containing details

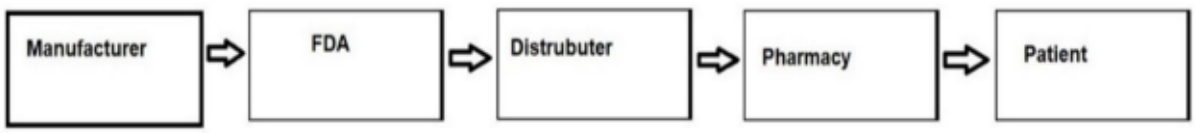

Figure 2.1: The traditonal healthcare supply chain with stakeholders

such as the producer ID, product ID, packaging identification code, and additional metadata. However the amount of information stored in data matrix code is limited compared to Quick Response (QR) scan.

2.3 Proposed Solution

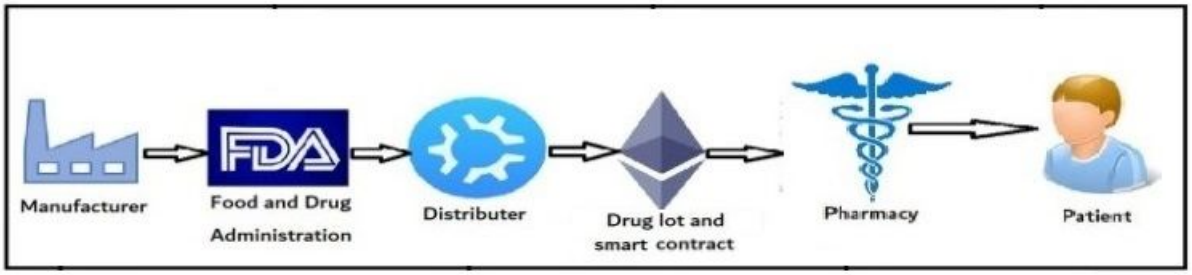

Figure 2.2: System architecture

The proposed solution is a decentralized blockchain system for traceability and regulation of medical products in healthcare supply chains. This system utilizes Ethereum blockchain technology to ensure the authenticity and privacy of traceability data, as well as achieve stable data storage.

Various stakholders in healthcare supply chain:

1. Manufacturer: Manufacturing medical products involves sourcing raw materials that meet quality standards, setting up a compliant facility, implementing quality control measures, following approved manufacturing processes, and maintaining detailed documentation. Adherence to regulations and ensuring product safety and efficacy are paramount.

2. Food and Drug Administration (FDA):The FDA can efficiently manage users in a blockchain-based system and play a critical role in discovering fraudulent medications while maintaining the quality and safety of pharmaceuticals.Only the manufacturer and other stakeholders are able to scan the QR code with the FDA's permission. FDA maintains a list of products, website visitors, and complaints .

3. Distributor:In the healthcare supply chain, distributors receive medicines from manufacturers and perform source verification to ensure the authenticity and legitimacy of the products. They carefully check the documentation, labels, and packaging to confirm the source. After verification, distributors assume ownership of the medicines and proceed with their distribution to pharmacies, healthcare providers, and other authorized channels.

4. Pharmacy:Pharmacies receive medical products from distributors in the healthcare supply chain. They play a vital role in verifying the source and ensuring the authenticity and quality of the products. Pharmacies then update their inventory to track available stock and maintain accurate records for efficient medication dispensing.Additionally, pharmacies meticulously update their inventory systems to accurately track the received products, their quantities, and expiration dates.

5. Patient:Patients play a vital role in the healthcare supply chain by verifying medication sources directly from the FDA. They can access the website to confirm the authenticity and safety of their medications. This process empowers patients to make informed decisions and mitigate risks associated with counterfeit or unsafe products. Consulting healthcare professionals is still important for personalized guidance.

2.3.1 Process

To address the challenges of counterfeit and substandard medicines in the healthcare supply chain, a proposed solution is the implementation of a ethereum based blockchain technology in supply chain tracking system. This solution leverages the transparency and immutability of blockchain technology to ensure the authenticity, safety, and quality of medical products from manufacturer to patient.Visualising the interface and functionality of the Healthcare Supply Chain in detection of fake products using a Use-Case Diagram given in figure 2.3 .

1. Upon approval, manufacturers would integrate their production and supply chain processes with the blockchain system. This integration involves recording key information regarding products onto the blockchain ledger. By doing so, manufacturers establish a secure and tamper-proof record of their products.

2. Distributors would receive medicines from manufacturers and perform thorough source verification. They would scan and record relevant information from the product packaging, such as unique identifiers, onto the blockchain. They can update the location.

3. Pharmacies would also verify the authenticity and quality of the products upon receiving them from distributors, updating their inventory systems accordingly.

4. The blockchain-based system enables real-time monitoring and traceability of medicines throughout the supply chain. Each transaction, from manufacturer to

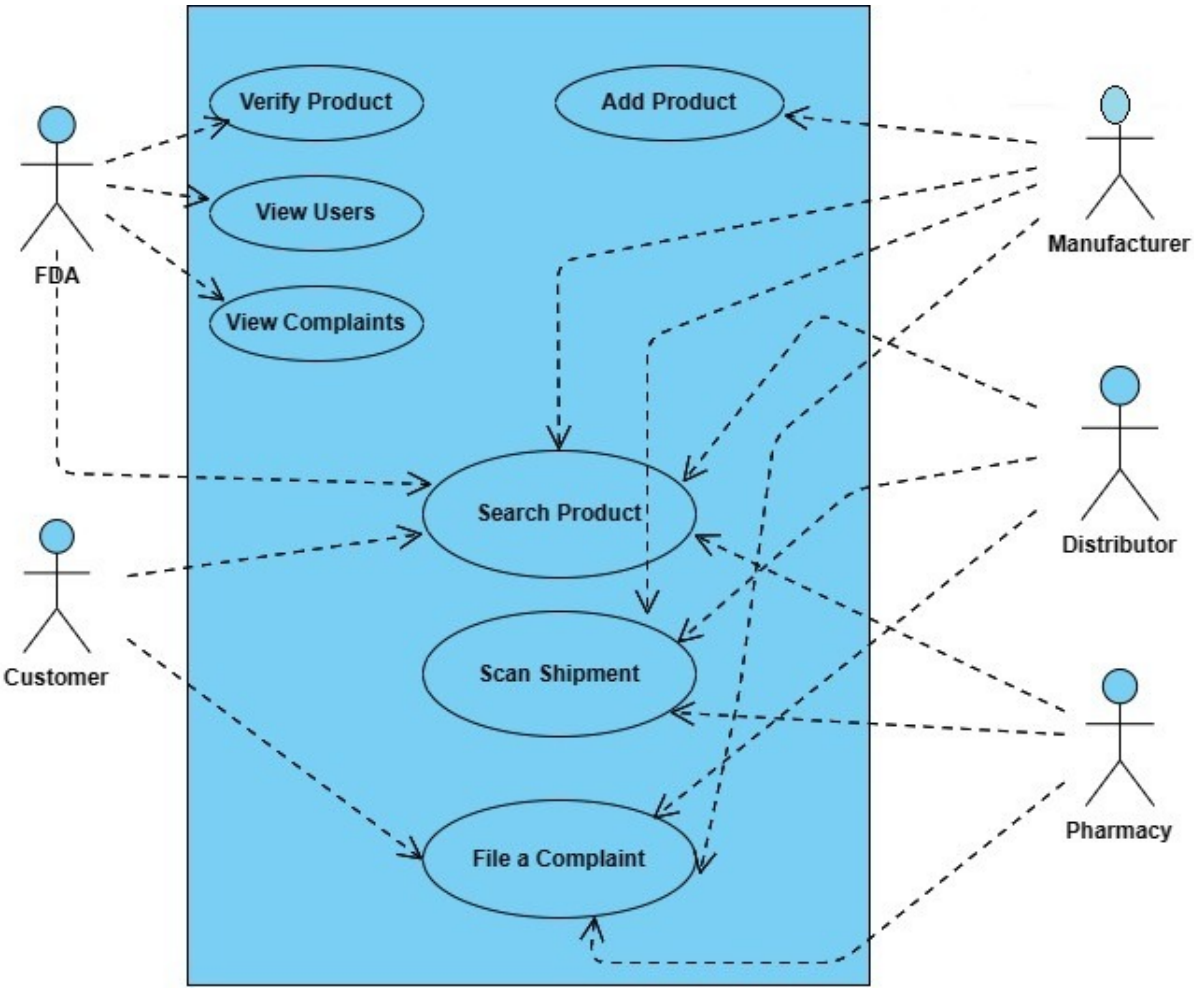

Figure 2.3: Use-Case Diagram

patient, would be recorded on the blockchain, creating an auditable and transparent trail of the product's journey. Any changes or discrepancies can be immediately detected and investigated by the FDA, ensuring swift action against counterfeit or substandard medicines.

5. Patients would have access to a user-friendly interface provided by the FDA, where they can verify the authenticity and safety of their medications. By entering the unique identifiers or scanning QR codes on the packaging, patients can confirm the legitimacy of the product and access detailed information about its source and manufacturing processes. This empowers patients to make informed decisions and protects them from the risks associated with counterfeit or unsafe products. They can file a complaint to FDA regarding fake medicines.

By implementing this blockchain-based supply chain tracking system, the healthcare industry can significantly reduce the circulation of counterfeit and substandard medicines. The transparency and immutability of blockchain technology ensures that only authentic and high-quality medications reach the patients. This solution

enhances patient safety, streamlines supply chain operations, and ultimately protects public health.

Overall, the proposed blockchain-based anti-counterfeiting system offers significant benefits, including enhanced consumer safety, improved supply chain transparency, and reduced costs for manufacturers. By leveraging the power of blockchain technology, this solution aims to combat counterfeit medical products, safeguard public health, and protect the interests of the healthcare industry.

Chapter 3

Literature Survey

Counterfeit medical products have become a significant issue in recent years, posing a severe threat to public health and safety. The World Health Organization (WHO) defines counterfeit medical products as those that are deliberately and fraudulently mislabeled with regard to their identity, composition, or source. These counterfeit products can range from substandard medications with insufficient active ingredients to entirely fake medicines that contain harmful substances.

One of the primary reasons behind the proliferation of counterfeit medical products is supply chain tampering. The complex and extensive global supply chains that exist in the pharmaceutical and healthcare industries provide ample opportunities for criminals to introduce counterfeit products into the market. Supply chain tampering refers to unauthorized interference or manipulation of the supply chain, which allows counterfeiters to introduce counterfeit or substandard products.

In their work, Petter Olsen et.al, address the issue of counterfeit medical products. They require a multi-faceted approach involving stakeholders across the supply chain, regulatory authorities, law enforcement agencies, and international collaborations. Implementing robust track-and-trace systems, enhancing supply chain transparency, strengthening regulatory frameworks, and raising awareness among healthcare professionals and patients are some of the strategies being employed to combat counterfeit medical products and safeguard public health[1].

According to research by Bougdira et.al, supply chain services have relied on barcode technology and RFID as primary identification techniques. These technologies, along with Wireless Sensor Network (WSN), have played a crucial role in gathering information and enabling effective monitoring of goods throughout different stages of the supply chain [2]. Additionally, EPC have been used to acknowledge, collect, and

transmit product data, facilitating seamless communication and tracking.

One notable barcode standard used in supply chain services is the GS1 barcode. GS1 standards, implemented by Smart-Track and other systems, incorporate a unique serial number that serves as the product's identity. In addition to the serial number, the GS1 barcode often includes information such as the lot production date and expiration date, providing essential details about the product's manufacturing and shelf life.

To ensure traceability, various supply chain procedures are implemented to capture the data encoded in the GS1 barcode as mentioned in [2]. This data is then utilized to maintain a comprehensive record of ownership transfers throughout the supply chain. By tracking these transfers, companies can effectively monitor the movement of goods and maintain visibility over their inventory.

The use of barcode technology, RFID, WSN, and EPC has significantly enhanced supply chain management by enabling accurate and real-time data collection, improving inventory control, and facilitating efficient logistics operations. These identification techniques, coupled with data capture and record-keeping practices, contribute to achieving the objectives of traceability, including the ability to obtain comprehensive data about a traceable resource across its lifecycle and track transaction records in real-time.

In their work, Saiyu Qi et al [3] proposed an enhancement to Cyphertest Policy Attribute Based Encryption (CP-ABE) by incorporating updateable encryption. This recommendation aimed to address certain challenges in the supply chain, particularly related to the use of RFID tags.

RFID tags have been employed in the supply chain to track and identify products throughout their journey. However, there are limitations associated with RFID technology. One of the challenges is that access to the data stored in RFID tags needs to be controlled according to attribute data regulations. CP-ABE is a cryptographic technique that allows fine-grained access control based on attributes assigned to users and data. By incorporating updateable encryption into CP-ABE, Qi et al proposed a way to enhance the access control mechanisms for RFID-tagged products in the supply chain.

In this system, each stakeholder involved in the supply chain acknowledges their possession of the product. For end users, such as patients, a single point of contact, organized through systems like the Global Data Syncronization Network (GDSN),

can be used along with a smartphone app to verify the validity of the product.

To ensure product verification and capture its specifications, pharmaceutical and healthcare departments can scan the barcode of the product within the production flow at the warehouse. A Data-Matrix monitoring system generates a unique Data-Matrix for each drug, containing crucial information such as the producer ID, product ID, packaging ID number, identification code, and additional metadata.

By utilizing the connected Data-Matrix, patients can verify the specific item they have received and confirm its authenticity. This system enhances transparency and enables patients to validate the product's origin and other relevant details associated with it.

Near Field Communication (NFC) tags are being explored to improve authenticity and visibility in the pharmaceutical supply chain. A recent initiative focuses on developing an NFC-based system for comprehensive visibility throughout the manufacturing process. Each pill is equipped with an NFC label for authentication and registration. Users can verify the medicine's authenticity and country of origin by scanning the NFC tag with a smartphone app.

By leveraging NFC technology, this initiative aims to enhance visibility, and supply chain security, and enable informed decisions for consumers. NFC tags attached to pills facilitate seamless authentication, allowing users to quickly verify the legitimacy of the medicine they possess. This advancement holds the potential for a safer and more transparent pharmaceutical supply chain.

Several researchers, including Corrado et al. [4], Supriya and Djearamane [5], and Jamal et al. [6], have proposed traceability solutions. However, these solutions share a common reliance on centralized databases, which presents certain challenges. One significant concern is the ease of tampering with goods information, as a centralized database can be vulnerable to malicious manipulation without robust safeguards in place. Detecting such tampering becomes difficult, undermining the integrity of the traceability system.

[6] uses centralized database across the proposed solution and it results in a lack of interoperability and scalability. The lack of standardization and compatibility between these databases hinders the seamless exchange of data and information between different stakeholders. This limitation poses challenges to achieving a comprehensive and efficient traceability system, especially as supply chain networks grow in complexity and scale.

Ilhaam A. Omar et al. in [7] propose a private blockchain-based solution for inventory sharing in the supply chain. Their system utilizes decentralization and Ethereum smart contracts for enhanced security. Thorough testing validates the solution, including cost and security analysis. However, stakeholder validation was not successful. Pinchen Cui et al. in [8] introduces a novel method for tracing electronic components using a permissioned blockchain. This technology is cost-effective and can prevent unlawful transfers and illegal device registration. However, the lack of distinctive identifiers leaves the system vulnerable to manipulation.

Consensus algorithms play a crucial role in blockchain networks, ensuring agreement among distributed nodes. Yash Madhwal proposes the Proof of Delivery (POD) algorithm in [9], which supports real-time visibility but involves lengthy verification of delivery compliance. Additionally, Pinchen Cui et al. discuss the Proof of Work algorithm, which requires solving computational challenges to generate new blocks.

A. Musamih et al., in [10] have utilized the Proof of Authority (POA) consensus mechanism, which is implemented in a private Ethereum Blockchain. This blockchain utilizes three smart contracts to control registration, production, and consumption. The front end of the blockchain is built using Dapps and web3.js libraries.

On the other hand, in [11] Xudong Tan et al. have adopted the Delegated Proof of Stake (DPOS) consensus algorithm, where delegates are selected based on their reputation and perceived reliability. Delegates are rewarded for good behavior, and members have the right to elect and replace them at any time. The pharmaceutical companies are organized into branch chains, which assist in departmental regulatory review and improve medication data detectability. DPoS systems often have a higher transaction rate per second compared to Proof of Work (POW) and Proof of Stake (POS) systems, but their safety for financial transactions is still a topic of discussion due to their relative novelty.

As mentioned by M. Rahouti et al. in [12] the concept of blockchain was first introduced in 2009 with the release of Bitcoin by Satoshi Nakamoto. Conditional transactions, later known as smart contracts, were introduced in the Ethereum Blockchain. In the context of drug traceability, the drug ledger employs a Unspent Transaction Output (UTXO)- based transaction model to illustrate the complete workflow of the supply chain, including packaging and repackaging processes. The system includes three distinct service providers: Certificate Service Provider, Query Service Provider, and Anti-Attack Service Provider, each serving a different role in the architecture.

Features	POW	POS	DPOS	POA
Type of blockchain	Permissionless	Permissionless	Permissionless	Permissioned
Type of network	Distributed	Distributed	Less Centralized	Centralized
Year	Firstly in 1993,reintroduced in 2008	2012	2014	2017
Speed	Low	Normal	Normal	High
Example	Bitcoin	Peercoin	Bitshares	Vechain
Tolerated power of adversary	Less than 25% computing power	Less than 51% stake	Less than 51% validators	Less than 51% nodes act maliciously
Block verification	Mining	Minting	Authenticators who are voted in	Private administrators

Table 3.1: Comparison between various consensus algorithm

The drug ledger is designed to defend against Sybil attacks, and a certified service provider is employed to ensure system security. According to research by Y. Huang et al. in [13] suggest that using UTXO for programming in drug traceability systems may not be very effective due to its high storage cost and low state space utilization .

Claudia Antal et al.,[14] proposes a smart contract-based monitor and tracking system for the management of COVID-19 vaccination supply on the Ropsten network. This system aims to improve the efficiency and transparency of the COVID-19 vaccine distribution process by ensuring traceability and conducting thorough audits of storage and delivery conditions. It also focuses on accuracy and transparency in the registration process and administration of the vaccination waiting list. The system provides a framework for openly reporting potential negative consequences. How-

ever, since Decentralized Applications (DApps) were not implemented in the author's system, digital apps rely on a single machine to function.

Rohit Raj et al.[15] utilize the Proof of Ownership mechanism in their proposed model. The model is continuous, decentralized, and digital, aiming to improve system performance and reduce latency using minimal resources. The authors focus on creating a transparent and traceable system, providing logistical businesses with real-time surveillance of pharmaceutical transportation. Ethereum, the underlying blockchain technology, is known for its faster transaction processing time compared to Bitcoin.

The solution presented in [16] by M. Muniandy et al. leverages the Ethereum blockchain and involves the use of a website built with JavaScript, HTML, CSS, and Solidity for smart contracts. The program is designed to track medications, enhance security, and increase transparency by identifying various parties involved in the supply chain, from the producer to the supplier of a specific drug. Although the proposed system utilizes smart contracts, there is no implementation described, making it difficult to fully comprehend the scope of the proposed solution as testing was limited to their local host environment.

In [17], H. R. Hasan et al. propose the combination of blockchain with the Interplanetary File System (IPFS). IPFS is a peer-to-peer network for file sharing that utilizes content-addressing to uniquely identify files in a distributed file system. This technology, when combined with blockchain, can effectively mitigate Sybil attacks and can be implemented as either a permissioned or permissionless blockchain. The algorithms used in IPFS are cost-effective compared to other alternatives, but it is often paired with other cloud storage platforms for massive data storage due to their own storage cost.

A. Kumar et al. in [18] conducts a preliminary examination of applying blockchain in the supply chain to address the issue of counterfeit medicines in the Indian market. The research utilizes Hyperledger Fabric v1.0 to establish a blockchain and develop a design for the drug distribution system. Digital certificates are used for identity allocation and privileges, and the blockchain facilitates network transactions.

H. M. Garcia et al. in [19], propose a system where the backend of the application is deployed in a cloud provider, with the IBM Blockchain service built on Hyperledger Fabric replacing the blockchain creation. The system ensures an extra security model as it operates as a private permissioned blockchain. The study includes qualitative and quantitative validation.

In [20] Varshad V et al. propose a system is to prevent drug fraud and enhance transparency, integrity, and accessibility in the healthcare supply chain using blockchain technology and the Amazon Simple Storage Service (AWS S3) service. The system allows only asset owners to transfer their authority to other stakeholders. It offers a non-repudiation technique for prompt conflict resolution in the drug supply chain, ensuring data collection, integrity, and traceability. The system also aids in identifying medications that lack active components and produces foolproof logs to detect counterfeit medicines.

In [21], R. Kumar presents a blockchain-based platform for the healthcare supply chain is presented. The system stores transactional information similar to Bitcoin transactions. Digital signatures and Public Key Infrastructure (PKI) are used to protect against man-in-the-middle and replay attacks. Stakeholder data is encoded as QR codes. However, the system is not fully decentralized, and there is a lack of transparency in the supply chain. The performance analysis using the Caliper evaluation tool showed a decline in performance and latency.

In [22], N. Alam et al. in addition to the techniques used in [21], add a Google Geolocation Application Programming Interface (API) to obtain real-time delivery location information. The system also optimizes data storage by removing information on expired products. Medication labels, ingredients, manufacturing expiration date, and amount are extracted from the drug packaging, and block generation is encrypted using Cyclic Redundancy Checksum (CRC-32) hashing. However, the system relies on the medication administrator, which poses a single point of failure.

In [23], G. Subramanian et al. introduce the New Economy Movement (NEM), a novel blockchain framework. NEM offers templates for smart contracts that can be executed outside of the blockchain, making them quick and programming-free. Developers can easily include smart contracts in apps using an API, ensuring speed and security. However, NEM lacks a scripting framework, restricting developers to use available resources and preventing the creation of custom smart contracts within NEM.

Q. Ding et al. in [24] proposes a permissioned blockchain with a double structure for product traceability data. The system consists of a base layer and a secondary layer. The top layer is built as a permissioned blockchain, while a private blockchain is created within the sublayer. Data entry and reading operations are segregated to improve efficiency and scalability. The double-layer architecture significantly en-

hances system performance and scalability compared to a single-layer approach. The suggested solution fully utilizes blockchain technology, providing a practical approach to improving product traceability and preventing data manipulation.

In [25] Raja Jayaraman et al. propose two blockchain-based distributed structures, Hyperledger Fabric, and Hyperledger Besu, are proposed for drug tracing. Hyperledger Fabric is a modular framework that provides security, dependability, adaptability, and scalability. The Membership Service Provider (MSP) element is used to identify and register medical stakeholders and create a permissioned private blockchain network. Hyperledger Besu is an open-source distributed ledger approach compatible with Ethereum. Both Hyperledger Fabric and Besu are designed for private and permissioned B2B structures, enabling faster state reconciliation and activity processing. However, the core components of the systems and the proposed user interface DApps have not been developed or implemented.

P. Zhu et al. in [26] enhance blockchain usage by incorporating the Practical Byzantine Fault Tolerance (PBFT) consensus technique for the traceability of medical supplies. The PBFT algorithm increases the number of honest nodes, making it difficult for successful attacks. The approach is energy-efficient and defends against single-point attacks using a distributed P2P architecture. However, the testing was performed on a single PC instead of a clustered deployment, and memory usage was not mentioned.

In [27] F. Xiong et al introduces a Construction Supply Chain (CSC) framework using blockchain to address issues in the conventional supply chain. Private key distribution protocols and a consensus algorithm are employed to enhance security. However, the mechanism for distributing private keys does not guard against attacks like history analysis and collusion assaults, and communication delays lead to time costs.

[28] involves the FDA in every step of the supply chain and highlights the potential disadvantages of using blockchain to combat counterfeit medical products. Interoperability between different platforms used by healthcare organizations can be challenging. The efficacy of the blockchain solution depends on the coding of smart contracts and the consensus technique used.

In conclusion, the analysis of the referenced papers highlights the advantages of using QR codes in our proposed system, as they eliminate the need for additional scanning devices like RFID, providing a cost-effective and accessible solution for

Features	Bitcoin	Ethereum	Hyperledger
Blockchain type	Public	Public or private or permissioned	Private or permissioned
Consensus mechanism	Proof of work	Proof of work or Proof of stake	Kafka or PBFT
Cryptocurrency	Bitcoin	Ether	No
Smart contract	No	Solidity and others	Chain node
Scalability	3-7 transactions per second	15-30 transactions per second	Scalable

Table 3.2: Comparison between various types of blockchain

all stakeholders. The utilization of the Ethereum blockchain for smart contract writing is justified by its public nature, ensuring transparency and immutability. To accommodate stakeholders' limited knowledge of blockchain, a hybrid storage system combining centralized SQL and decentralized (Ethereum blockchain) approaches is implemented, offering convenience and familiarity while leveraging the benefits of blockchain technology. This integrated approach aims to create a user-friendly and efficient supply chain system, enhancing transparency, security, and overall user experience.

Chapter 4

Architecture and System Design

4.1 Architecture

Figure 4.1 illustrates the complex data exchange and stakeholder collaboration in the decentralised web application for secure supply chain operations. The login page serves as the primary entrance point and directs users to the appropriate pages based on their account type. Each user will have a customised experience thanks to this personalised interface. Users have the opportunity to make a complaint if they find a fraudulent product by uploading the product's id or QR code and a description of it, starting a quick feedback process to resolve the problem.

The manufacturer responds by starting the process of scanning the produced QR

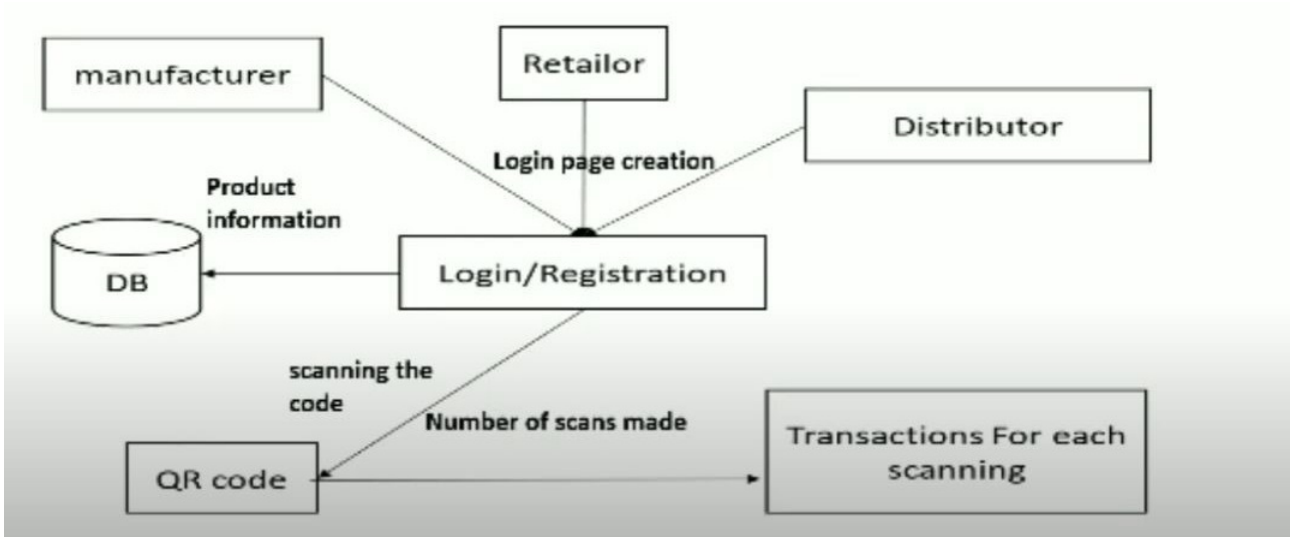

Figure 4.1: Data-Flow Diagram

code based on the prescription received from the pharmacy after receiving FDA verification of the medication. Throughout the manufacturing process, adherence to regulatory regulations and quality standards is crucial. The manufacturer

simultaneously delivers merchandise to reputable distributors who are in charge of delivering the goods to the specified places safely and effectively.

Following notification, the distributor assumes control of the distribution procedure, ensuring the safe transfer of the products and preserving the integrity of the supply chain. The distributor reimburses the producer for the purchase price in order to uphold accountability and transparency, promoting fair business practises. After receiving the delivery, the pharmacy completes the payment to the manufacturer, encouraging smooth cooperation and confidence between stakeholders.

Additionally, the pharmacy is able to place extra orders as needed thanks to the interaction with the decentralised web application and database, guaranteeing effective inventory management. Patients, who are the real beneficiaries, buy the goods from the pharmacy and use a QR code scanner to confirm their legitimacy. By offering real-time verification and reducing the risks connected with counterfeit or subpar items, blockchain technology securely maintains product information. Figure 4.1's comprehensive system creates an efficient data flow and stakeholder participation, improving transparency, security, and the overall integrity of the healthcare supply chain.

The diagram 4.2 illustrates the flow of interactions between the stakeholders in the healthcare supplychain.

The interactions between the six key parts of the healthcare supply chain solution—manufacturer, FDA, smart contract, distributor, pharmacies, and patient—are shown step-by-step in this sequence diagram.

i. Manufacturer: Supply acquisition from reputable sources initiates the production process. prior to being sent for FDA approval. When medical products are manufactured, the FDA should verify the authenticity of the products before approving them.

ii. FDA: When the manufacturer's supplies are being verified and approved, the FDA is an essential player. The manufacturing procedure cannot start distribution of medicine in the market unless the FDA verifies it.

iii. Manufacturing and Smart Contract: Drug and medical product distribution is started by the manufacturer as soon as FDA verification is permitted. To securely store and maintain the product details, a smart contract is constructed and deployed at the same time. The corresponding product ID is produced when the manufacturer scans the QR code. He then gives it to the distributor.

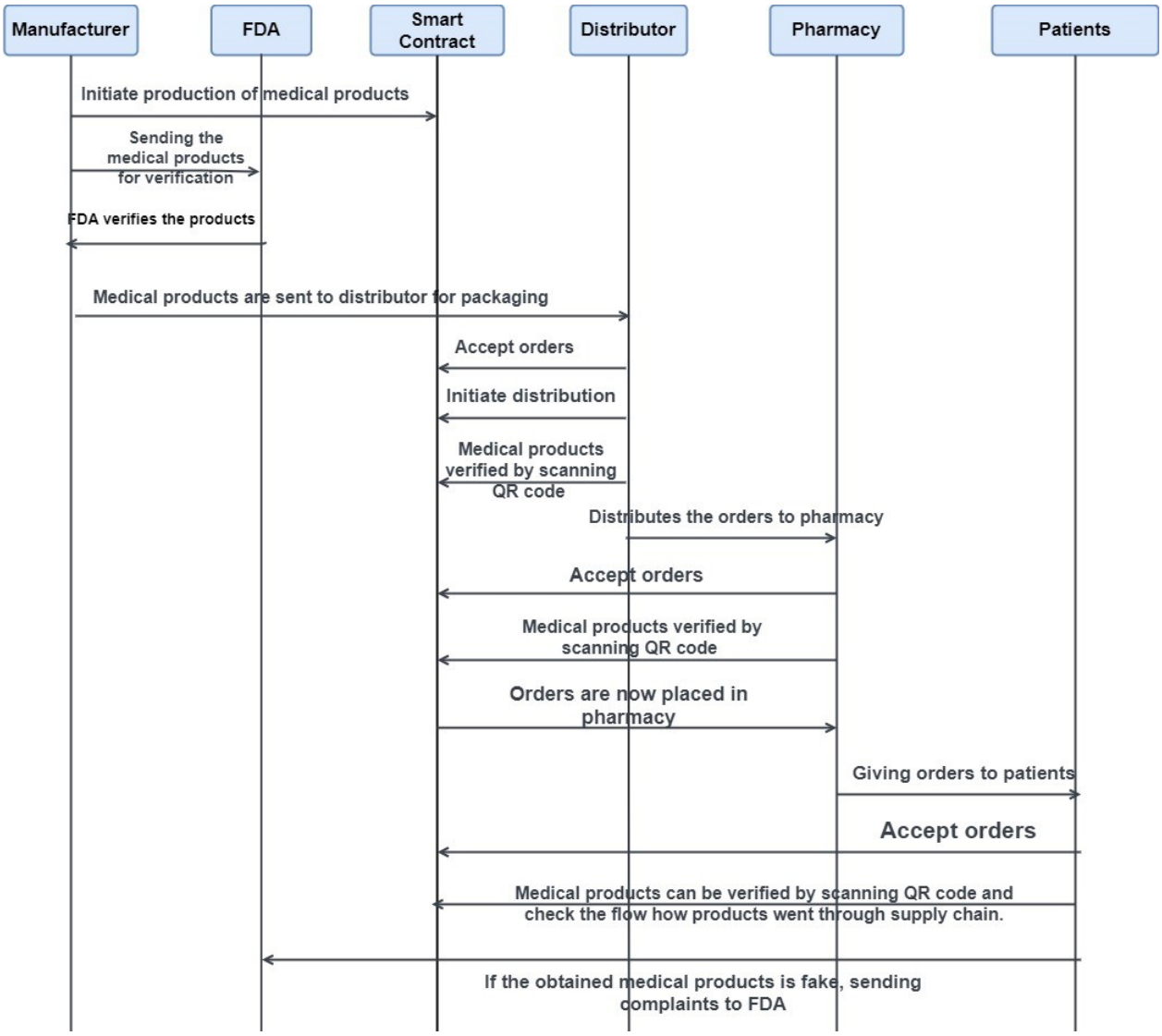

Figure 4.2: Sequence Diagram

iv. Distributor verification: The distributor is in charge of delivering the goods to other stakeholders after the production process is finished. By scanning the identical QR code on the medical products to preserve the chain of custody, the distributor verifies the products' integrity and conducts extensive verification.

v. Delivery to Pharmacy: The distributor sends the tested goods to pharmacies, where ownership is transferred. The pharmacies scan the QR code to verify the authenticity of the merchandise and update their inventory systems to appropriately reflect the received goods.

vi. Smart contract integration: Throughout the supply chain process, relevant information, such as product details, product ID, and verification records, are securely stored within the smart contract. Verification done by manufacturer, FDA, distributor and pharmacy is also recorded. This integration ensures transparency, traceability, and immutability of the information.

vii. Patient Verification: Patients may finally confirm the legitimacy and safety of their drugs. Patients can verify the product's origin, quality, and other crucial facts by scanning a QR code or gaining access to the system, enabling them to make educated decisions about their healthcare. If the manufacturer, FDA, distributor, and pharmacy have all confirmed the QR code, the product is authentic; otherwise, the patient acquired a fake.

In order to protect the integrity and safety of pharmaceuticals along the healthcare supply chain, manufacturers, the FDA, distributors, pharmacies, and patients have been working cooperatively. This thorough sequence diagram demonstrates their efforts.

4.2 System Design

4.2.1 Manufacturer

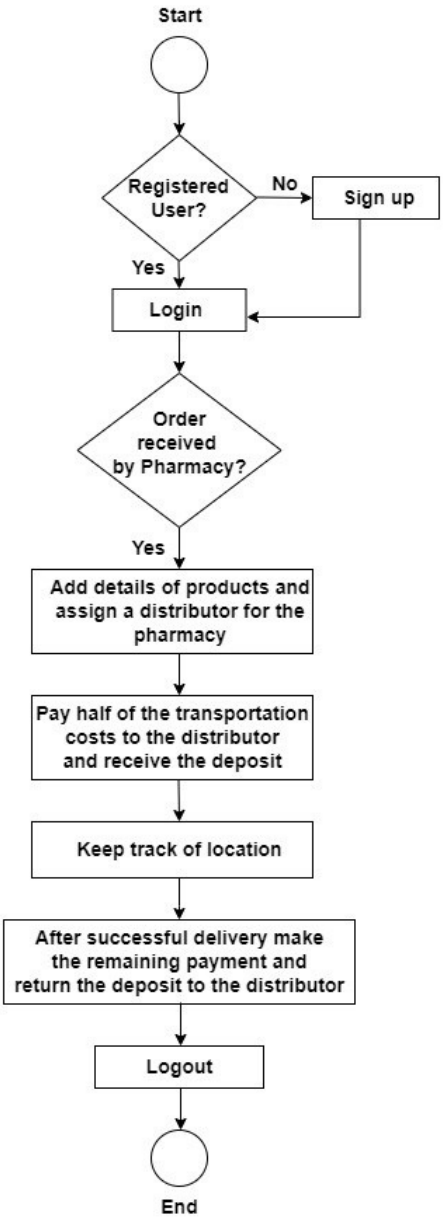

Figure 4.3: Manufacturer's Process flowchart

The figure 4.2 illustrates the process for a manufacturer. It begins by checking if the manufacturer is a registered user. If they are, they can proceed to log in to their account. Once logged in, the manufacturer checks for any orders. If there is an order, they add the product details to the blockchain, ensuring transparency and immutability. Next, the manufacturer assigns a distributor for the transportation of the product. To initiate the shipment process, the manufacturer pays half of the transportation cost to the distributor. In return, the distributor provides a deposit as security. The manufacturer then scans the shipment and records the date and location

information into the blockchain, allowing for tracking throughout the delivery process. Upon successful delivery of the product, the manufacturer makes the remaining payment to the distributor for their transportation services. The manufacturer also returns the deposit to the distributor, signifying the completion of the transaction. Finally, the manufacturer logs out of their account, concluding the process.

4.2.2 Distributor

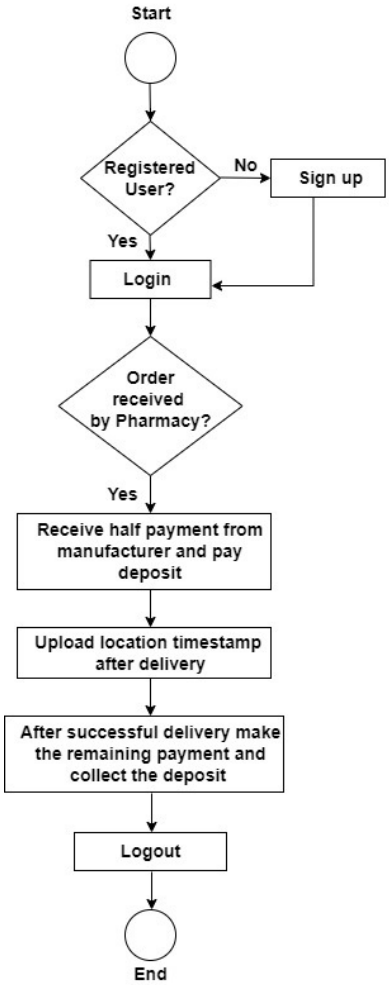

Figure 4.4: Distributor's Process flowchart

The figure 4.3 illustrates the process for a distributor. It begins by checking if the distributor is a registered user. If they are, they can proceed to log in to their account. Once logged in, the distributor checks if the pharmacy has received the orders. If they have, then the distributor will receive half the payment from the manufacturer and pay the deposit. Next, the distributor will upload the location details which will be stored in the blockchain. Upon successful delivery of the product, the distributor will receive remaining payment and collect the deposit. Finally, the distributor logs out of their account, concluding the process.

4.2.3 Pharmacy

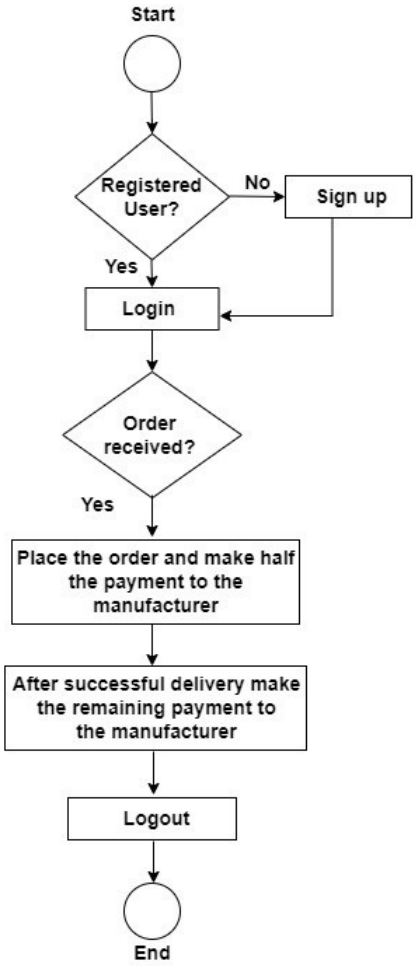

Figure 4.5: Pharmacy's Process flowchart

This figure 4.4 demonstrates the process of a pharmacy. It begins by checking if the pharmacy has already created an account. If they have , they can login directly and check if have received the orders. After they place the order, the pharmacy pays half of the amount to the manufacturer The pharmacy can also verify the products received by scanning the qr code. They can also update the location details confirming the order received. Finally, the pharmacy can log out of their account.

4.2.4 Consumer

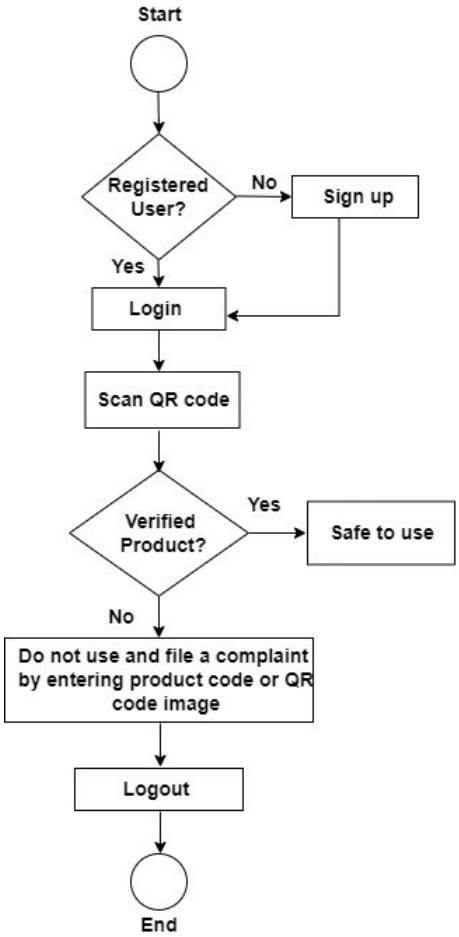

Figure 4.6: Consumer's Process flowchart

The figure 4.5 demonstrates the process of consumers.The consumer can either log into their account or create a new account. The consumer can verify the product that they have received by scanning the QR code. If the product that they have received is counterfeit, they can file a complaint by sending an email or entering the details about the product in the website.

Chapter 5

Implementation

5.1 Implementation Platform

5.1.1 Hardware

i) Processor: AMD Ryzen 5 3600 4.2Ghz 6 cores 12 threads

ii) RAM: 16GB DDR4 3533 MT/s

iii) GPU: Nvidia GeForce RTX3070 8GB

iv) Storage platform: NVME SSD(

5.1.2 Software

i) Operating System: Windows 11

ii) Software Used : MetaMask, Truffle, Ganache, Remix IDE, Web3.js

iii) Programming Languages : HTML, CSS, Javascript, PHP, Solidity

iv) Server: XAMPP server

5.2 Implementation Details

The implementation of the counterfeit product detection project focused on utilizing the Ethereum blockchain for its robustness and support for smart contracts. Ethereum's smart contract functionality allowed for the automation of verification and tracking processes, ensuring transparent and tamper-proof record-keeping.

To interact with the Ethereum blockchain, the MetaMask extension was incorporated, providing a user-friendly interface for seamless interaction within web browsers as shown in figure 5.1 .

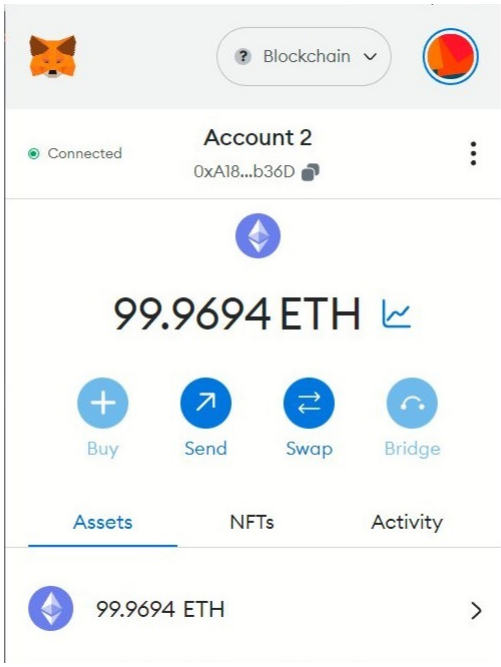

Figure 5.1: Metamask extension

Testing was conducted on the Ganache test blockchain, enabling efficient debugging without incurring actual transaction costs.The Ganache blockchain application is provided in the figure 5.2 .

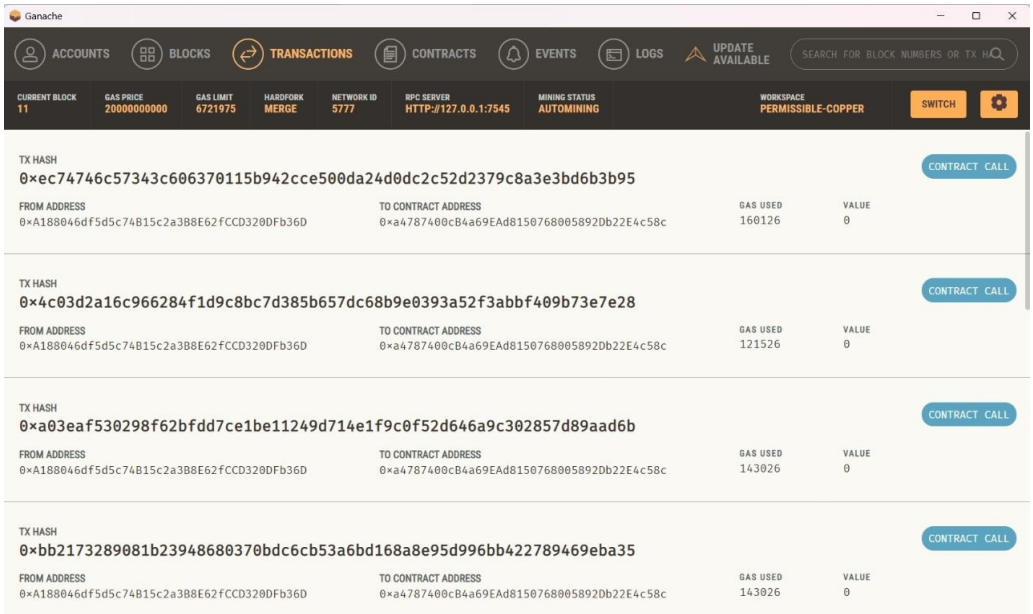

Figure 5.2: Ganache application

QR code generation and scanning were facilitated using the Qrious npm package, simplifying the process and enabling stakeholders to verify product authenticity. The project's website was hosted on an Apache PHP server for compatibility, stability, and efficient handling of HTTP requests.

Web3.js and Truffle were utilized to interact with the blockchain smart contract.

Web3.js acted as a bridge between the application and Ethereum, allowing interaction and data retrieval from the deployed smart contract. Truffle simplified the development, deployment, and testing of smart contracts.

Remix IDE served as the online development environment for smart contract coding and hosting, providing a user-friendly interface for writing, compiling, and deploying smart contracts.

The project incorporated stakeholders' shipment location data to track the movement of medical products and verify their authenticity.

By leveraging these technologies and methodologies, the implementation ensured a robust and secure solution for detecting counterfeit products, enhancing patient safety, and maintaining the integrity of medical supply chains.

Chapter 6

Results and Discussion

6.1 Results

In the results section of the report, we highlight the main objectives and achievements of the project. The project primarily focuses on three key aspects: adding products to the Ethereum blockchain, scanning shipments for recording date and location information, and using QR codes to access product details and associated shipment data.

To add products to the Ethereum blockchain, we leverage the capabilities of

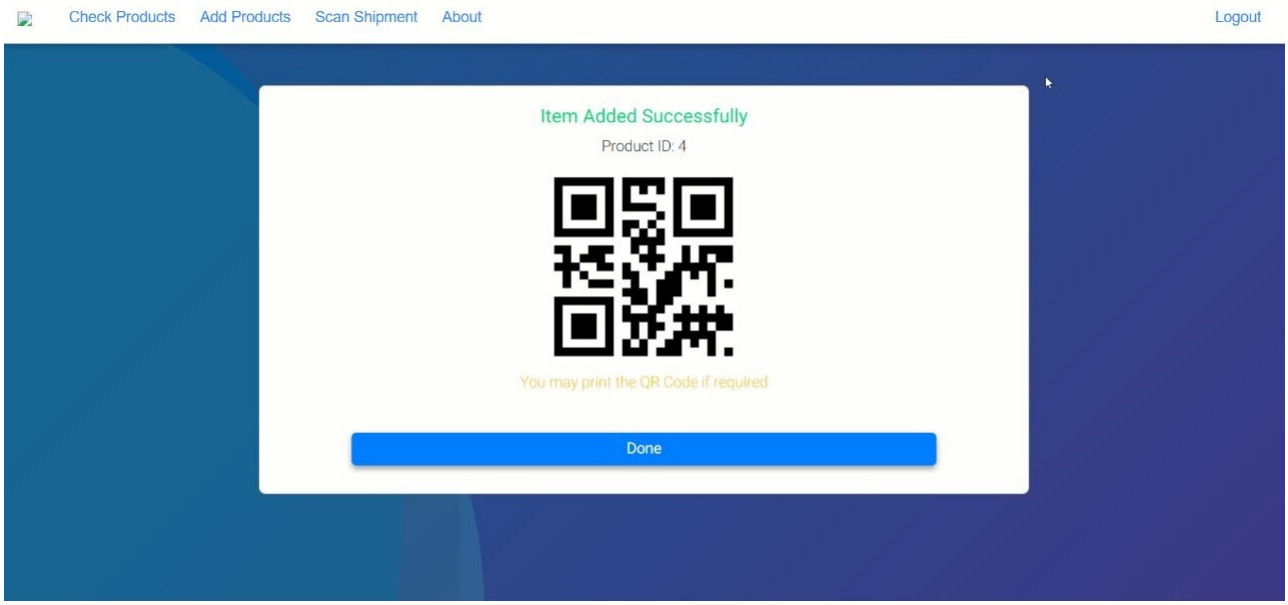

Figure 6.1: Add product page

MetaMask, which serves as a connection to the test blockchain Ganache. This integration allows us to interact with the blockchain, enabling the secure storage of product information such as product details, manufacturing data, and any other relevant data points.The QR code is generated when manufacturer add the product

which contains product ID as shown in the figure 6.1

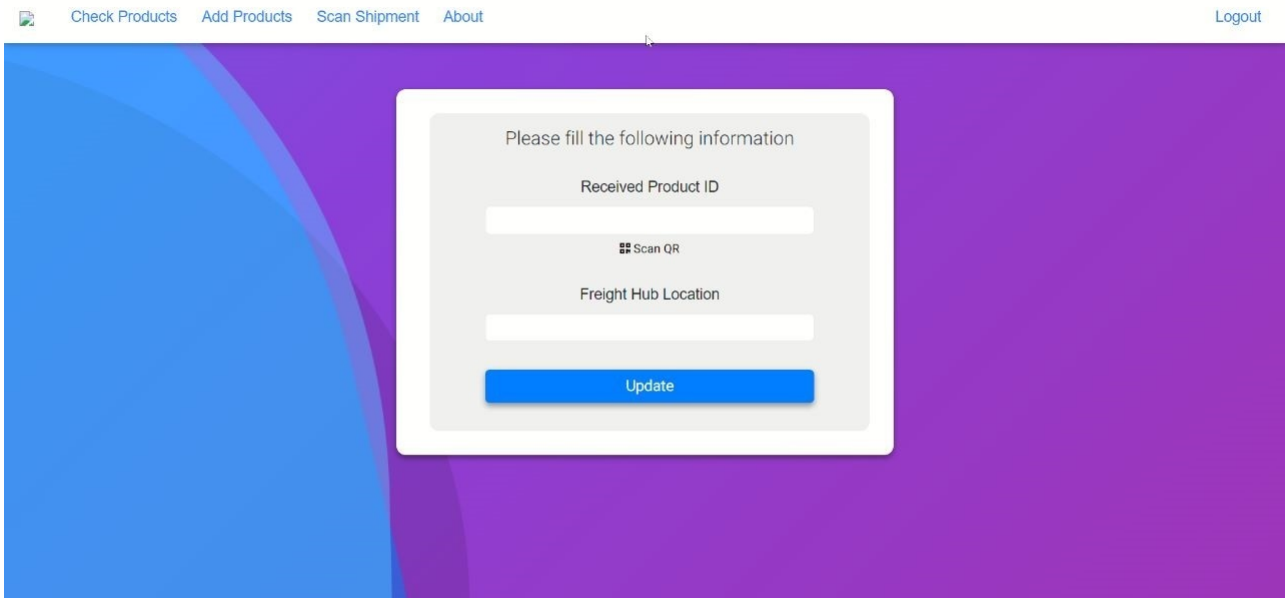

Figure 6.2: Scan shipment page

The scanning of shipments plays a crucial role in the project.The scan shipment page is shown in figure 6.2 .Each stakeholder involved in the supply chain process can scan the shipment using a designated tool or application. By scanning the shipment, stakeholders can add the date and location information to the blockchain. This process ensures transparency and traceability throughout the product's journey, enabling all parties to have real-time access to the latest shipment status.

Furthermore, the project incorporates the use of QR codes.These codes contain

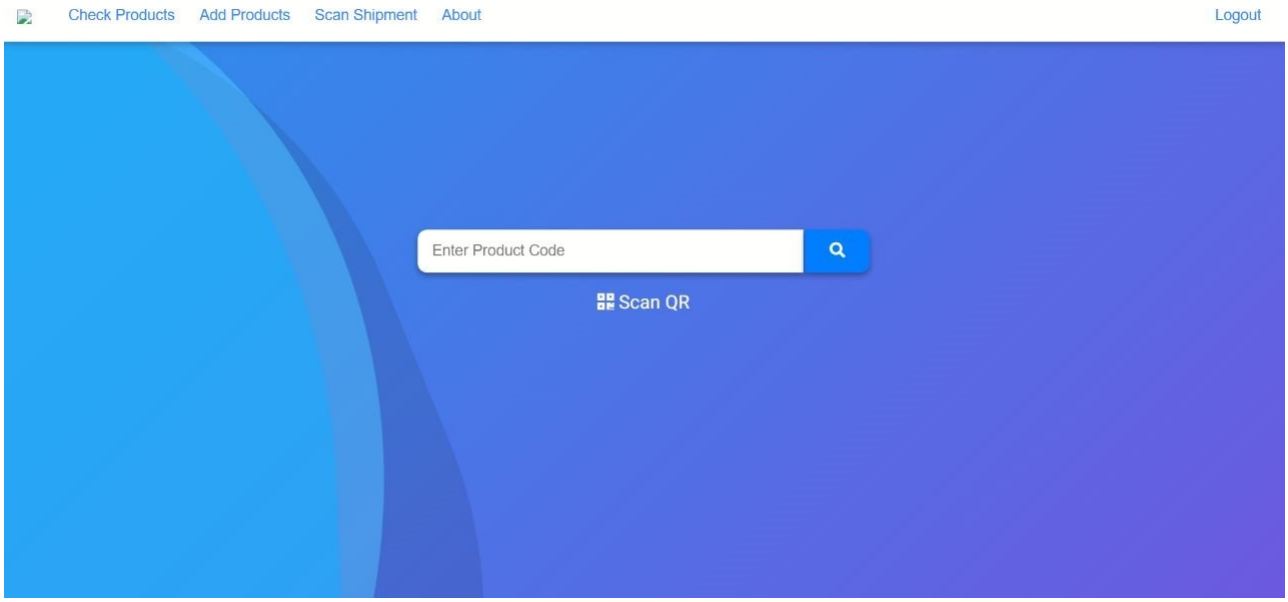

Figure 6.3: Check product page

unique identifiers that link to specific products and their associated blockchain records.The figure 6.3 shows how the QR codes are used to check the products. By scanning the QR code, stakeholders can retrieve comprehensive details about the product, including manufacturing information, shipment history, and the date and locations recorded by each stakeholder at different stages of the supply chain. This feature enhances transparency and facilitates easy access to vital product information for all stakeholders.

6.2 Discussion

The presented report illustrates the utilization of blockchain technology to establish drug traceability within the pharmaceutical supply chain. While the smart contract's functionalities were initially designed with the pharmaceutical industry in mind, they can be readily adapted for various other supply chains. The primary distinction between the pharmaceutical supply chain and other supply chains lies in the nature of the products being transported, distributed, and sold, as well as the specific handling requirements throughout the process. For instance, pharmaceutical drugs often necessitate precise conditions such as temperature and humidity during transportation, whereas a spare parts supply chain would have different criteria. Although this project does not incorporate real-time tracking, tracing the origin of a product/item, irrespective of its type, follows a similar procedure. It involves scanning a unique identification code attached to the product/item, with the subsequent handling managed by the DApp.

6.2.1 Security Analysis

Within this subsection, we provide a concise overview of the security analysis conducted on the proposed blockchain-based solution designed for the healthcare supply chain. The evaluation encompasses essential security objectives, including integrity, accountability, authorization and non-repudiation, emphasizing their significance in the context of the solution.

1. Integrity: The fundamental aim of the suggested blockchain solution is to maintain the integrity of transactions transpiring within the healthcare supply chain, thereby guaranteeing the traceability of Lot history.

2. Accountability: As exemplified in the previous sections, the Ethereum address of

the caller is recorded on the blockchain for each function execution, enabling traceability of the function's initiator. Consequently, all participants are held accountable for their actions. In the healthcare supply chain, this implies that the manufacturer bears responsibility for any drug Lot they produce.

3. Non-Repudiation: The utilization of cryptographic signatures, where transactions are signed with the private keys of their initiators, ensures non-repudiation. The cryptographic properties of PKI prevent the derivation of private keys from public keys. Consequently, a transaction signed by a specific private key can be directly attributed to the owner of that key. This concept aligns with accountability within the blockchain-based healthcare supply chain, as participants are unable to deny their actions since they are securely signed by their private key, which is linked to their authentic identity.

4. MITM Attacks: In the blockchain environment, every transaction necessitates the signature of the initiator's private key, rendering Man in the Middle (MITM) attacks infeasible. This attribute holds significant importance in the healthcare supply chain application, as it guarantees that only verified entities possess the ability to execute actions within the supply chain. Consequently, potential intruders attempting to illicitly manufacture counterfeit drugs under the guise of a verified manufacturer will be prevented from doing so.

6.2.2 Limitations of Blockchain in Pharmaceutical Supply Chains

While the proposed system capitalizes on the notable advantages of blockchain technology, it is essential to acknowledge several potential limitations that may impact the system. By outlining these limitations, we aim to provide a comprehensive understanding of their potential implications on the proposed blockchain-based healthcare supply chains. The following discussion delves into the potential constraints associated with blockchain technology in this context.

1. Immutability: One inherent characteristic of blockchains is their immutability, meaning that any information added to the ledger cannot be modified or deleted. While this feature contributes to data integrity, it also poses a significant challenge. In cases where inaccuracies occur, such as errors made by operators during the recording of information in the drug supply chain, there is no straightforward way to correct these errors once they have been detected due to the immutability of the blockchain.

2. Interoperability: One challenge in blockchain technology is the lack of interoperability between different blockchain networks, aside from Ethereum. Each blockchain operates in its own distinct manner, resulting in difficulties when attempting to establish communication and data exchange between different blockchains. To circumvent this issue, the adoption of a unified blockchain-based solution across healthcare centers can mitigate interoperability problems. However, if healthcare centers opt for different blockchain-based solutions on various platforms, achieving interoperability becomes considerably challenging.

3. Efficiency: The efficiency of the blockchain solution relies significantly on the coding of the smart contract and the chosen consensus algorithm for transaction verification and confirmation. The quality of the smart contract coding determines the implementation and execution costs, while the consensus algorithm influences energy consumption levels. Considering the substantial number of transactions involved in the healthcare supply chain, it is crucial for the smart contract to be well-coded, ensuring swift and efficient execution.

Chapter 7

Conclusion and Future Work

7.1 Conclusion

In conclusion, the proposed solution of implementing a blockchain-based supply chain tracking system in the healthcare industry holds great potential in addressing the challenges posed by counterfeit and substandard medicines. By leveraging the transparency, immutability, and real-time monitoring capabilities of blockchain technology, the solution aims to ensure the authenticity, safety, and quality of medical products from manufacturer to patient.

With the integration of manufacturers, thorough source verification by distributors and pharmacies, and the empowerment of patients to verify medication sources directly, the proposed solution establishes a secure and tamper-proof record of medicines throughout the supply chain. This enables quick detection of counterfeit or substandard drugs, facilitates swift actions to safeguard public health, and empowers patients to make informed decisions.

The collaboration and data sharing among stakeholders fostered by the blockchain system further enhance supply chain efficiency and transparency, strengthening the overall integrity of the healthcare supply chain. While the implementation of this solution requires collaboration and coordination among manufacturers, regulatory bodies, distributors, pharmacies, and patients, the potential benefits in terms of patient safety, improved quality control, and streamlined operations make it a worthwhile endeavor.

By embracing this blockchain-based supply chain tracking system, the healthcare industry can take a significant step forward in mitigating the risks associated with counterfeit and unsafe medicines, ultimately ensuring the well-being and trust of patients.

7.2 Future Work

Our future objectives include incorporating the participation of the FDA, allowing them to directly engage with stakeholders and provide approvals for manufactured products. We intend to expand the system by incorporating additional information about the drug lots, implementing an external storage system to store images associated with each drug lot. Our ongoing efforts are centered around enhancing the efficiency of pharmaceutical supply chains. We aim to extend the proposed system to achieve end-to-end transparency and verifiability of the products.

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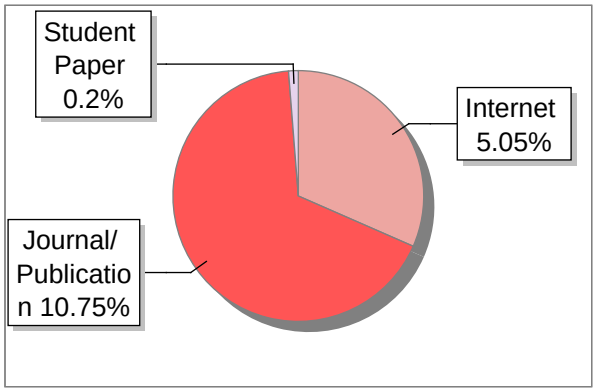

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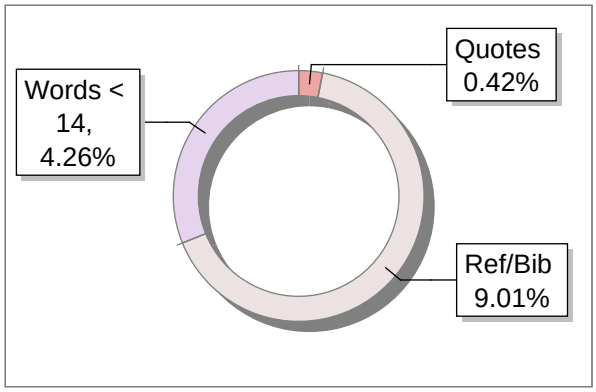

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Detection of Counterfeit Medical Products

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Abstract: Medical product counterfeiting is one of the many major problems facing the healthcare sector. It is estimated that 10 to 30 percent of medical products sold are fake. Because they do not have access to quality healthcare, these issues are more prevalent in undeveloped and developing nations. As the healthcare supply chain is centralised and the procedure from the product's creation to its delivery to the user is opaque, it is challenging to identify counterfeit goods. As a result, the traceability of medicinal products becomes crucial. In addition to the difficulties of data privacy, data authenticity, and adaptability, traditional methods have not been very effective in resolving these problems. In this study, we reviewed several blockchain-based approaches for detecting fake medical items that employ the Ethereum blockchain, Hyperledger fabric, etc. The adoption of innovative ideas, like the inclusion of a QR code which enables customers to discover more about medical products are also studied. We also discuss the various architectures and techniques that are employed. The key challenges faced, and the research gaps are also analysed.

I. INTRODUCTION

From the purchase of basic materials toward the distribution of the final item to the clients, the supply chain is an intricate structure composed of various separate businesses. The counterfeiting of medical supplies is just one of the issues that a system this intricate is sure to have. Not only are fake medical items bad for patients, but they also cost the pharmaceutical and healthcare sectors a lot of money. Such problems must be fixed, and measures to boost supply chain system transparency should be done. With the introduction of blockchain inside the supply chain industry, transparency may be addressed. The core concept with a blockchain is similarly to something like a linked list in where both retain a replica of information that had been previously present with in nodes who came before them. Numerous industries have adopted the blockchain. With no need for a centralised authority, a peer-to-peer network was created with the aid of these produced apps. The detection and traceability of medicinal products can be accomplished utilising a variety of blockchain-based solutions. This article also focuses on the obstacles and restrictions associated with applying blockchain technology to the healthcare industry. The stakeholders in a general medical supply chain are Food and Drug Administrator (FDA), the manufacturers, the distributor, the pharmacies and finally the customer.

A. Motivation

A serious threat to society is posed by the counterfeiting of pharmaceuticals. The people's health is adversely affected by the fake medications, and the actual pharmaceutical manufacturing companies suffer financial losses as a result. The pharmaceutical industry's counterfeit medication problem is partly a result of the broken supply chain structure. There have been several anti-counterfeiting strategies proposed up to this point, however most of the existing systems are subpar. When we require both data access and data privacy, blockchain technology is one of the greatest options available. Consequently, we are seeking to use blockchain technology to guarantee the quality of the medicine, the security of the transaction, and the accuracy of the data.

II. LITERATURE SURVEY

A. Traditional Efforts

The capacity to obtain any or all data regarding the entity within investigation across its life cycle using documented identifications is known as traceability. The thing being examined is known as a traceable resource. A unit interaction is any measurable unit inside the logistics network. Tracking the transaction records and the transaction's location in real - time basis are the two objectives of traceability. [1].

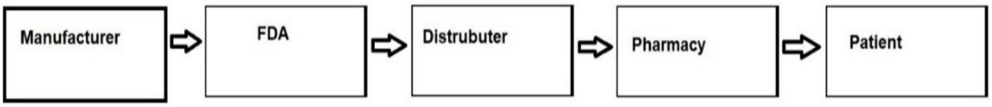

Figure 1. The traditional healthcare supply chain with stakeholders

In the past, supply - chain services utilise barcode technology and Radio frequency identification as identification techniques, as well as wireless sensor networks (WSN) for gathering information but also electronic product codes (EPC) to acknowledge, gather, and communicate product data in order to support the monitoring of goods through various stages. [2].The GS1 standards barcodes used in this context by Smart-Track [3] contain a unique serialised product identity, a Lot production date, and an expiration date. Various supply chain procedures capture the data found in the GS1 barcode, which is then utilised to keep a running record of ownership transfers.

In [4] Saiyu Qi et al recommended adding the ability for updateable encryption to Ciphertext Policy Attribute Based Encryption (CP-ABE). RFID tags were on the products throughout the supply chain. Despite the fact that attribute data regulations control access to data and RFID tags are scalable, they are expensive and most likely won't function if radio frequency waves collide. There won't be accurate results.

As each stakeholder acknowledges having the product in their possession, an end user (patient) may verify validity over a single point of contact organised like Global Synchronization Network (GDSN) via using a smartphone app. To verify the items and their specifications, pharmaceutical as well as healthcare departments would scan the barcode inside the production flow at the warehouse. The Data-Matrix monitoring system [5] creates a Data-Matrix for each drug that includes the producer ID, product ID, id Number of the packaging, identification code, and extra meta-data. The patient may confirm under which item was created by using the connected Data-Matrix.

Figure 2. Data Matrix

NFC tags have recently been proposed as a technique to improve authenticity and visibility along the whole pharmaceutical supply chain. Regarding this, [6] details an initiative to develop an NFC-based system that permits visibility throughout all stages of the pharmaceutical manufacturing process. Each pill has an NFC label attached to it that is used for authentication and registration. Similar to the first available methods, the user or patient may verify the validity or country of origin of the medicine by scanning the associated NFC tag with a smartphone application.

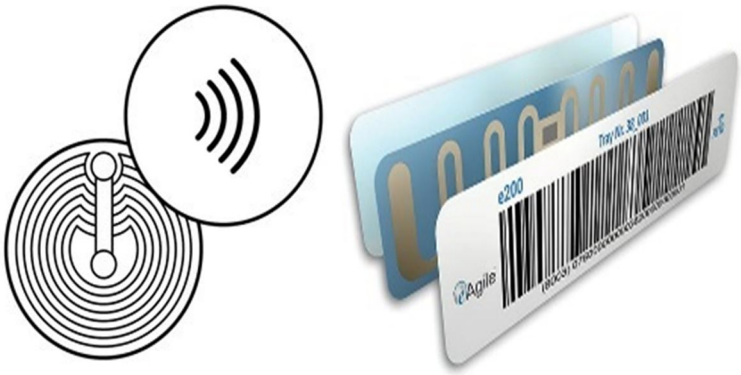

Figure 3. NFC and RFID tags

The systems for traceability in [9] use centralised databases, which make it very simple to tamper with products information and challenging to spot. In addition, the utilisation of many centralised databases may leave the proposed solutions with limited scalability and interoperability.

B. Blockchain Based Approach

In addition to all the previously stated conventional approaches, Ilhaam A. Omar et al [10] suggest a private blockchain-based solution that makes use of decentralised storage and Ethereum smart contracts to enable inventory sharing among supply chain participants. Through thorough testing of numerous situations and system functionalities, the proposed solution is validated.

They have analysed the costs and security to show that the plan can be implemented. However, it failed to validate the stakeholders.

In [11] Pinchen Cui et al introduce a novel method to trace the electronic components in the supply chain, they used a permissioned (consortium) blockchain in their suggested system. They choose whether to include the transaction in blocks using miners. This technology is inexpensive and may be applied both on chain and off-chain. It stops unlawful transfers and fault transfers, as well as illegal device registration. Due to the lack of PUF and other distinctive identifiers, the device is vulnerable to manipulation within the network.

Blockchain networks rely on consensus algorithms to reach an agreement among various distributed nodes. One such algorithm proposed by Yash Madhwal in [12] is the Proof of Delivery (PoD) algorithm.It supports real-time information visibility but has lengthy verification of compliance with the delivery terms. [11] discusses the Proof of Work algorithm, a consensus mechanism that includes solving difficult computational challenges to produce new blocks.

[13] puts forward the Proof of Authority (PoA) consensus mechanism. it is used in a private Ethereum Blockchain, which has three smart contracts to control registration, production,and consumption. The front end of the blockchain is built using Dapps and web3.js libraries.

[14] Adopted the Delegated Proof of Stake (DPoS) consensus algorithm, whose delegates are chosen based on their standing and perceived reliability. Delegates are rewarded for excellent behaviour, as according DPoS proponents, since the members has the rights to elect them out and substitute them at any moment. They organised the pharmaceutical companies employing DPoS onto branch chains, in which the main chain's structure and the branch chains' structure were helpful for departmental regulatory review and it would also dramatically cut the amount it required for medication data to be detectable. With a larger transaction rate per second than blockchains powered by PoW and PoS systems, DPoS systems are often speedier. But because DPoS is still relatively new, it is not usually seen as being safe enough to serve as the foundation for blockchains that conduct financial transactions.

In 2009, Satoshi Nakamoto released bitcoin, which served as the first use of the blockchain concept [15]. It had a concept of conditional transactions which was later introduced as a smart contract in Ethereum Blockchain. The drug ledger employs a UTXO-based transaction model to show the full workflow of the supply chain from start to finish. It includes packaging and repackaging processes, which are crucial to drug traceability. The service provider has been divided into three distinct elements, namely the Certificate Service Provider, the Query Service Provider, and the Anti-Attack Service Provider, according to a different architecture.

The drug ledger's construction is done in a way that it can fend off Sybil attacks. To ensure system security, a certificate service provider is employed. The medication ledger is effective at resolving packaging, unpackaging, and repackaging issues. Recent research has revealed that using UTXO for programming, together with its high storage cost and low state space utilisation, is not very successful when used in drug traceability systems [16].

In [17] Claudia Antal et al propose a smart contract-based monitor and tracking system for the management of COVID-19 vaccination supply on the ropsten network. It improves the COVID-19 vaccine distribution process' efficiency and transparency by ensuring traceability and conducting a thorough audit of the conditions for storage and delivery. It also ensures accuracy and openness in the registration process as well as the administration of the vaccination waiting list. It offers a framework for openly reporting potential negative consequences. Because DApps have not been implemented in the author's system, digital apps must rely on a single machine to function.

In [18] Rohit Raj et al, have used Proof of Ownership in their paper. The proposed model is continuous, decentralised, and digital. To improve system performance and decrease latency, very few resources were utilised. In order to create transparent and traceable system, the authors used. Logistical businesses are given access to real-time surveillance of pharmaceuticals being carried out. Ethereum just needs 10 to15 seconds to process a transaction compared to Bitcoin's 10 to 12 minutes.

The proposed solution in [19] makes use of the Ethereum blockchain. Additionally, there is a website that uses JavaScript, HTML, CSS, and Solidity for smart contracts. Due to the inclusion of blockchain technology, the programme is helpful in tracking down medications. In terms of security and increased openness in identifying the many parties, from the producer to the supplier of a particular drug, it also demonstrated excellent results. The proposed system makes use of smart contracts, but there hasn't been any implementation, which makes it difficult to comprehend the full scope of the suggested fix since testing was limited to their local host.

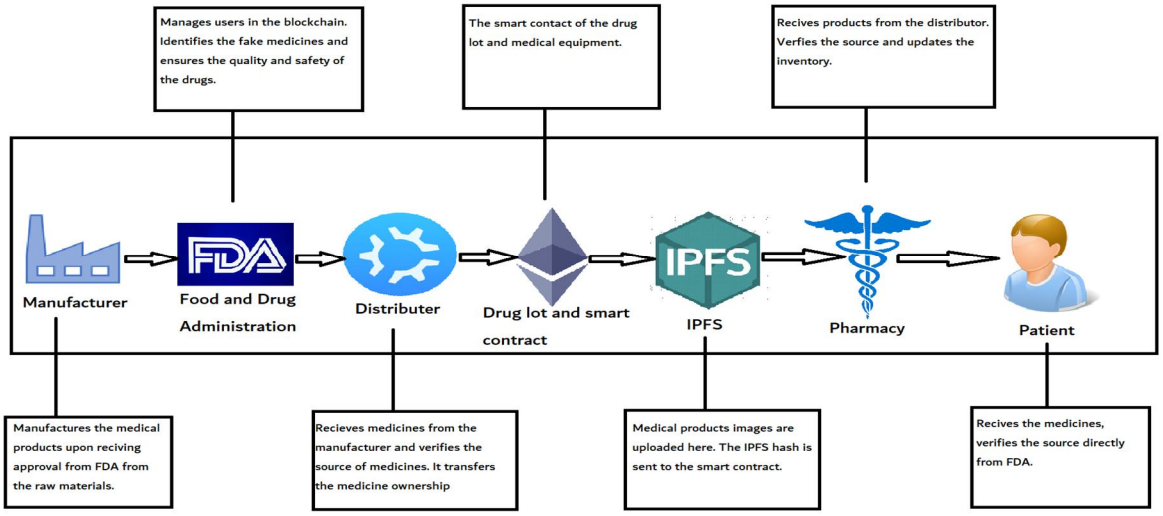

Figure 4. Blockchain based solution for healthcare supply chain

[20] combines the blockchain with the Interplanetary File System (IPF), a protocol, hypermedia, and peer-to-peer network for file sharing that is used to store and share data in a distributed file system. Each file in a global namespace connecting IPFS servers is uniquely identified via content-addressing, which is used by IPFS. The technology is quite effective at thwarting Sybil assaults and can be quickly set up as either a permissioned blockchain or a permissionless blockchain, depending on the need. Furthermore, because the algorithms don't use loops or arrays, they are cheaper than other alternatives that have been suggested. For massive data storage, it is typically paired with other cloud storage platforms because it is expensive for storage.

[21] does a rough examination of the application of blockchain inside the supply chain to address the problem within the Indian merchandise for fake medications. In Hyperledger Fabric v1.0, a blockchain is established and used to launch this research. Second, in allocating identity and privileges via digital certificates and maintain network transactions, a design of the drug distribution system is developed.

The backend, which serves as an API for the front end, and the application were both launched as in cloud provider in [22]. The IBM Blockchain service, which is built in Hyperledger Fabric which is private permission and ensures an extra security model, has replaced the creation of the blockchain. It provides both qualitative and quantitative validation.

First one gives customers a sense experience, and it asked individuals whether they would be open to using an app to confirm the medications they had brought. It was accepted 92% of the time. The second one concentrated on the system's performance once many people entered it, however it resulted in time-out issues. Additionally, the authentication component validates the user's credentials to ensure their identity before granting access to the system in accordance with their assigned role.

[23] makes use of the Ethereum blockchain which is created using AWS. Each and every transaction in the medical supply chain is recorded and timestamped. It has smart contracts that control the creation and transfer of goods. In comparison to Huang et al.'s Drugledger, the PharmaCrypt approach is more user-friendly because it eliminates concepts like query service provider and certification service provider. PharmaCrypt uses bar code scanning technology, so it doesn't need sensors. The implementation process is expensive. To make the proposed solution more practical, it needs to take less time to complete the transaction. Because it relies on the AWS service and is based on the AWS blockchain, barcode scanning is not a very effective solution.

Utilising the Blockchain technology The goal of [24] is to prevent drug fraud and enhance the transparency, integrity, and accessibility of the healthcare supply chain utilizing Blockchain technology and indeed the AWS S3 service. Only individuals who are the owners of those assets have the choice to transfer their authority to other stakeholders. For the prompt settlement of any conflicts in the drug supply chain, the suggested system offers a non-repudiation technique that identifies the collection of knowledge, offers proof of its integrity, and exhibits traceability. It aids in identifying medications that lack intended active components. The device is able to produce foolproof logs, which aid in locating fake medicines.

The suggested approach uses Blockchain technology's cryptographic underpinnings to protect logs of occurrences across the supply chain, ensuring drug safety and eradicating counterfeits. One of the drawbacks of utilizing this method is that AWS limits resources by default. Hence the complete utilisation
cannot be made.

[25] presents a trustworthy blockchain-based platform for healthcare chain supply across stakeholders. The storage of transactional information is what makes it similar to bitcoin transactional information. With the use of digital signatures and PKI, the system is protected against man-in-the-middle and replay attacks. Data given by the stakeholders is shown as encoded QR codes. The author has not fully decentralised the system, and there is a lack of transparency in the supply chain. PKI and digital signatures are used in the offered method to protect against man-in-the-middle as well as replay attacks. During the performance analysis, the Caliper evaluation tool showed a decline in performance and latency.

In Addition to the techniques used in [25], [26] made use of google Geolocation API to get real-time location of the delivery of the product. Along with that it also removed information of the expired products, thereby optimizing the data storage. For block generation, which is encrypted using CRC-32 hashing, the
medication labels, ingredients, manufacturing expiration date, and amount are extracted from the drug packaging. Its sole flaw is that the medication administrator represents one system failure.

TABLE 1. Table showing various consensus algorithm

Features	Proof of Work	Proof of Stake	Proof of Authority	Delegated Proof of Stake
Blockchain type	Permissionless	Permissionless	Permissioned	Permissionless
Network type	Decentralized	Decentralized	Centralized	Less centralized
Speed	Low	Normal	High	Normal
Tolerated power od adversary	Less than 25% computing power	Less than 51% stake	Less than 51% nodes can act maliciously	Less than 51% validators
Verification of block	Mining	Minting	Private administrators	Authenticators who are voted in
Year	Firstly in 1993, reintroduced in 2008	2012	2017	2014
Example	Bitcoin, Litcoin	Peercoin, Casper	Microsoft Azure, Vechain, Xodex	Bitshares

[27] presents a novel blockchain framework which is the New Economy Movement (NEM). It offers templates for smart contracts that are executed outside of the blockchain, which makes them quick and free of the need for programming. A smart contract can easily be included in apps by developers using an API. As a result, it is quicker and safer. But because NEM lacks a scripting framework, the developer is only able to use the available resources and cannot create their own smart contracts using NEM.

As a solution for product traceability data, [28] presented a permissioned blockchain including double structure. A base layer and a secondary layer make up the system. The Permissioned type of blockchain is built on the top layer. A private type of blockchain is built inside the sublayer. To increase efficiency and scalability, operations like data entry and reading are segregated. The double layer considerably boosts system performance and is comparable to multi-layer architecture. Resources are typically used up quickly during data storage processes. In a two-layer system, the sub-layer is responsible for data entry and storage while the main layer manages query activities. As a result, the performance is enhanced. The scalability is significantly enhanced by the double layer. Additionally, it enhances overall performance and promotes customer utility. The suggested solution makes full use of blockchain. It offers a practical approach to enhancing product traceability and preventing data manipulation.

[29] have proposed two workable blockchain-based distributed structures, Hyperledger Fabric and Besu, that address key requirements for drug tracing, including confidentiality, trust, integrity, security, authorization and authentication, and scalability. Hyperledger Fabric is a framework for distributed ledger applications, and its modular design provides high levels of security, dependability, adaptability, and scalability. The Health Authority uses the membership service provider (MSP) element of the suggested Hyperledger Fabric architecture to identify and register all medical stakeholder and their end customers, creating a permissioned private type of blockchain network. The suggested Hyperledger Besu drug tracking design is an open - sourced distributed ledger approach that is completely compatible with Ethereum and may be used by businesses looking for blockchain architectures that are compatible with it. Unlike Ethereum, Besu and Hyperledger Fabric are designed to be used as private and permissioned B2B structure. Besu plus Hyperledger Fabric enable faster state to reconcile and activity processing. On the downside, neither the system's core components nor the proposed designs' user interface DApps have indeed been developed or put into use.

[30] has enhanced the blockchain's traditional usage by involving a novel Practical Byzantine Fault Tolerance (PBFT) consensus technique to increase system performance during the traceability of medical supplies. This is one of the essential steps to ensure anticounterfeiting as it involves the consensus of all the nodes to support the veracity of the drug information. The number of honest nodes is gradually due to the enhanced PBFT algorithm. Since the proportion of corrupt nodes to authentic nodes would be so much lower than the threshold for a successful attack, the recommended technique is therefore assured to be exceedingly difficult to attack. Their approach uses less energy, which increases the acceptability of blockchain technology for medical traceability and anti-counterfeiting. The recommended method defends against single-point assaults by utilising a distributed P2P architecture. The disadvantage of this method is that, instead of employing a clustered deployment, just one PC was used for operation and testing, and memory usage was not mentioned.

[31] utilizes a new CSC framework to avoid the issues seen in the conventional supply chain. A construction supply chain using blockchain is called the CSC framework. They also used private key distribution protocols, which have 10 sub-protocols, to implement the recovery of private keys and a consensus algorithm is used. It guards against attacks on network protocols as well as secret-sharing techniques. The transmission expenses, additional delays, and information loss are addressed and are considered in traditional CSC. However, the mechanisms for distributing private keys do not guard against attacks like history analysis and collusion assaults. Time costs arise due to communication delays.

[32] created the BIOT3 system for supply chain monitoring and tracing, which includes of five layers combining blockchain and the IOT (Internet Of Things). The platform is verified using the Hyperledger Fabric Blockchain. It allows multilayer monitoring and visibility of medicinal products as well as integrity inside this supply chain paradigm. Smart contract-based alert mechanisms are used to verify information regarding fake medication goods. O n and off-chain storage are provided in the implementation. The supply chain in real-time is more complicated. Therefore, firms are responsible for the actual implementation of this one.

[33] engages the FDA in every step of the supply chain, whereas the conventional supply chain approach did not. Therefore, this leads to the verification of the stakeholders but also the products and the processes. It also outlines potential disadvantages of utilising blockchain to find counterfeit medical products. Firstly, it will be very challenging to make blockchain based solutions used by healthcare organisations that choose to use various platforms interoperable. Second, the efficacy of the blockchain solution depends on both the coding of the smart contract and the consensus technique used to validate and approve a transaction.

TABLE 2. Comparison of various blockchain types

Features	Bitcoin	Ethereum	Hyperledger
Cryptocurrency	Bitcoin	Ether	No
Consensus	• Proof of Work	• Proof of Work • Proof of Stake	• PBFT • Kafka
Type	• Public	• Public • Private • Permissioned	• Private • Permissioned
Smart Contract	No	Solidity and others	Chain node
Scalability	3 to 7 transactions per second	15 to 30 transactions per second	Scalable

III. CONCLUSION

To counteract the sale of fake medicines, this article examines the issue of medication tracing within pharmaceutical supply chains. We looked into a number of conventional and blockchain-based approaches for distributed drug monitoring and tracing in the healthcare supply chain. We have also investigated several blockchain networks like Ethereum, Hyperledger, and others, as well as different consensus algorithms like Proof - Of - work, Proof - Of - stake, and others. We considered the advantages and disadvantages of these strategies and came up with added features like Google's Geolocation API enabling real-time monitoring, QR codes allowing product authentication, including FDA participation throughout each step of the medical supply chain.

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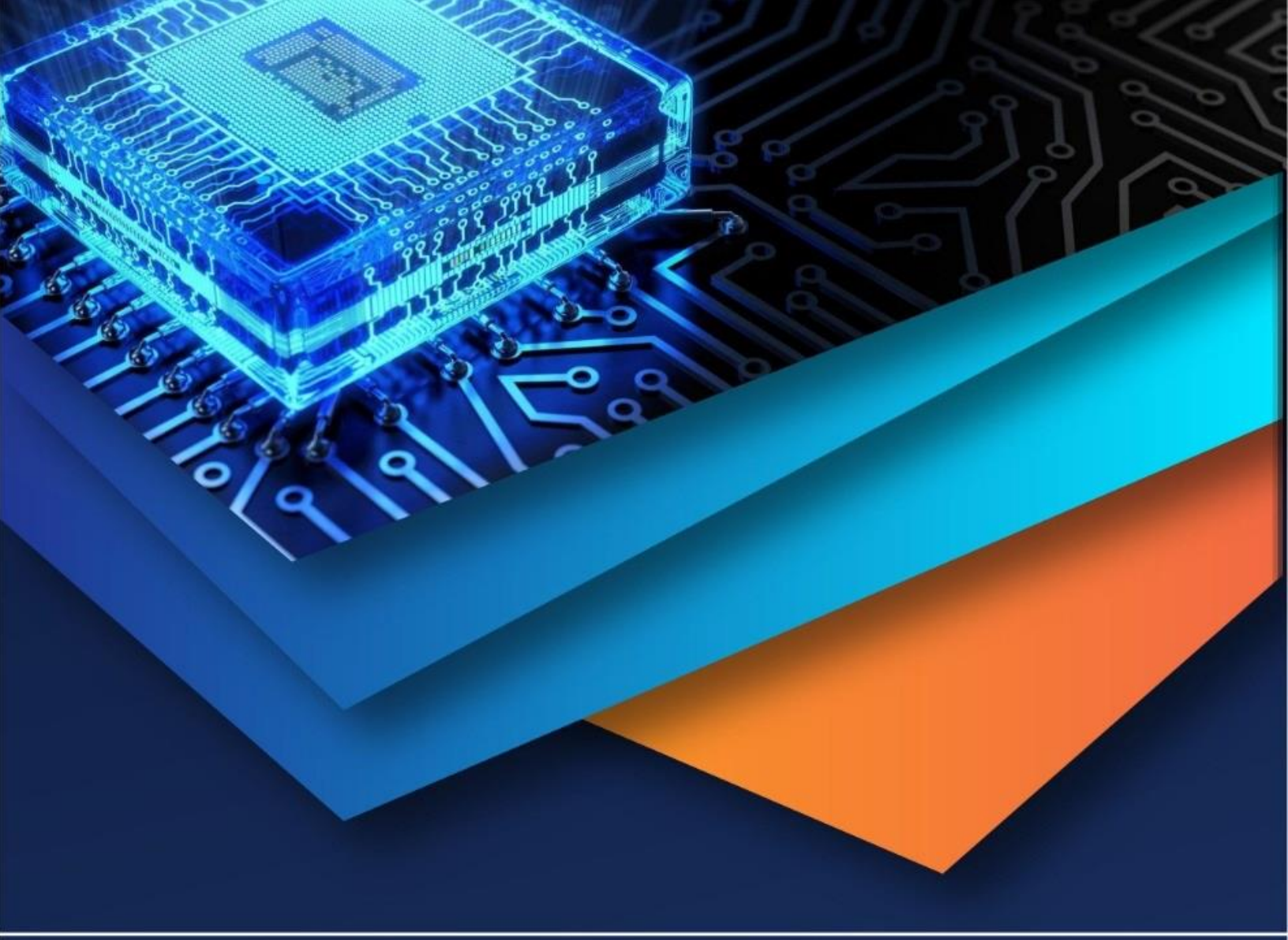

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