Drug Traceability in HealthCare Supply Chain using Blockchain Technology

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ABSTRACT.

Rising circulation of falsified and low-quality medicines has become a growing global concern, threatening patient safety and weakening confidence in healthcare systems. Achieving transparency, authenticity, and accountability in the pharmaceutical supply chain remains a persistent challenge for both industry stakeholders and regulatory authorities. Blockchain technology provides an innovative solution through its decentralized and tamper-proof digital ledger that permanently records each transaction across the entire drug lifecycle. This study explores how blockchain can be applied to ensure complete traceability of medicines, securing every stage from manufacturing to distribution and retail dispensing In a blockchain-driven environment, all participants—manufacturers, wholesalers, distributors, and pharmacies—share a common, permissioned network. Each drug batch carries a unique digital signature, enabling continuous tracking and validation throughout its journey. Automated smart contracts facilitate verification, eliminating unauthorized handling and minimizing human error. When integrated with technologies such as the Internet of Things (IoT) and QR-based identification, blockchain enables Realtime monitoring of product movement and storage conditions, thereby improving operational efficiency and compliance with regulatory frameworks. The proposed model enhances supply chain transparency and allows authorities and consumers to authenticate products instantly. It also minimizes financial losses linked to counterfeit drugs while reinforcing public trust in pharmaceutical brands. This research underscores the potential of blockchain to strengthen healthcare logistics and establish a secure, transparent, and efficient drug distribution ecosystem. In conclusion, blockchain transforms traditional methods of pharmaceutical tracking by ensuring data integrity, reliability, and end-to-end visibility. Its adoption can drastically reduce counterfeit circulation, streamline supply chain operations, and contribute to a safer, more dependable healthcare infrastructure

Keywords: Blockchain Technology, Pharmaceutical Supply Chain, Drug Traceability, Counterfeit Medicines, Smart Contracts Internet of Things (IoT), Data Integrity.

1.Introduction

In many ways, the healthcare sector is the most important part of any country's economy, and this is because it is an essential part of people's lives, contributing to their health and well-being. The healthcare sector includes a wide range of enterprises, from research to industrial production to facility management. Organisations in the healthcare sector provide medical services, manufacture medical equipment and drugs, and facilitate the delivery of healthcare to patients. The bedrock of healthcare provision is effective supply chain management. This slowing to the fact that the administration of high-quality healthcare depends on the availability of medical consumables to patients at the appropriate times and in the appropriate quantities; otherwise, patients may not receive the quality care they deserve Effective supply chain management in healthcare will reduce costs, improve efficiency, and in most cases will add agility and resilience to the healthcare value chain. Due to the growing prevalence of fake and subpar drugs on the global market, the topic of drug traceability has attracted a lot of attention recently. For patient safety and the overall effectiveness of the healthcare system, it is essential to ensure the authenticity and quality of pharmaceuticals. Drug tracking and tracing has proven difficult for conventional supply chain systems, necessitating the use of more sophisticated technologies. The creation of blockchain-based supply chain platforms for drug traceability is one potential remedy. With its decentralised and secure nature, blockchain technology has the ability to completely change how pharmaceuticals are tracked and traced throughout the supply chain. In this paper, we propose a blockchain-based solution that will overcome the present issues of traceability in the pharmaceutical supply chain.

2 . Literature Review.

In recent years, the Ministry of Health has made major strides in increasing the public's access to comparative data on quality, finances and patient satisfaction. Several mechanisms at multiple levels help promote quality improvement and patient safety. These include legislation, financial incentives, and national programs for quality indicators, patient experience, patient safety, prevention and control of infection and accreditation. Over the years, improvements in quality indicators, infection prevention and patient satisfaction can be demonstrated, but other fields show little change, if at all. Challenges and barriers include reluctance by unions, inconsistent and unreliable flow of information, the fear of overpressure by management and the loss of autonomy by physicians, and doubts regarding "gaming" of data. Accreditation has its own challenges, such as the need to adjust it to local characteristics of the healthcare system, its high cost, and the limited evidence of its impact on quality. Lack of interest by leaders, lack of resources, burnout and compassion fatigue, are listed as challenges for improving patient experience. Although health outcomes have improved in low-income and middle-income countries (LMICs)in the past several decades, a new reality is at hand. Changing health needs, growing public expectations, and ambitious new health goals are raising the bar for health systems to produce better health outcomes and greater social value.

3. Methodology & System architecture.

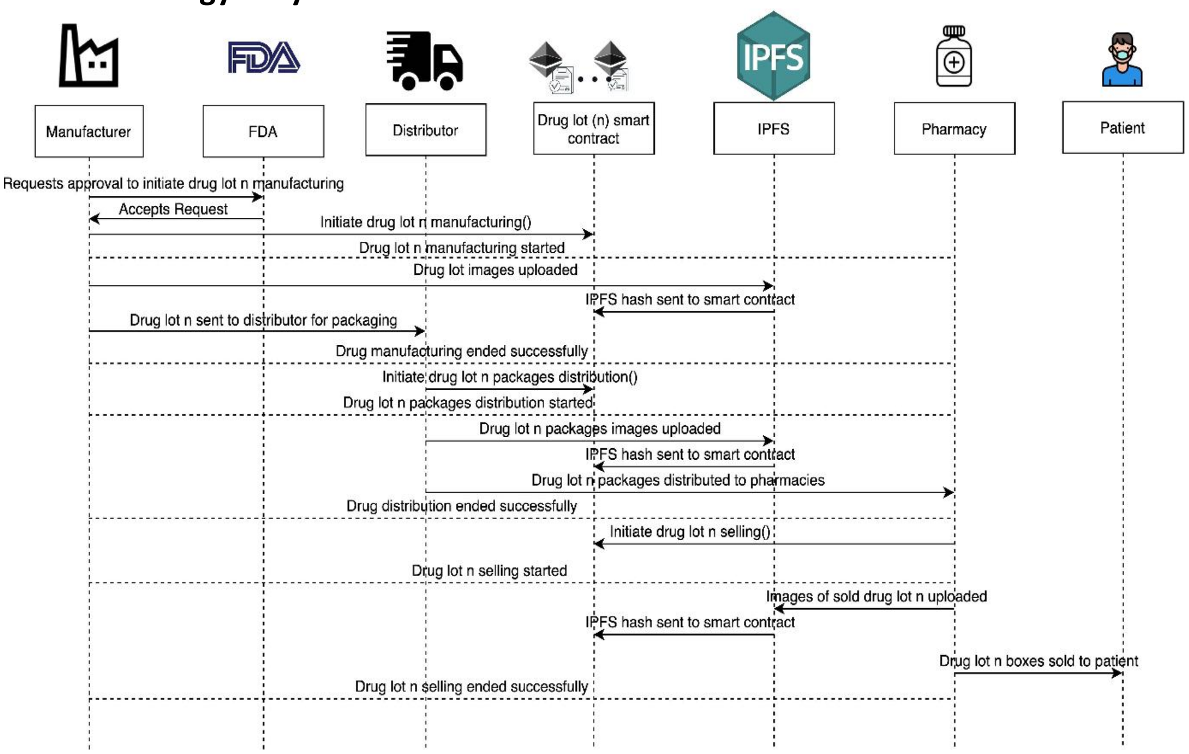

Fig 3 Workflow of drug tracebility using blockchain

Forty-eight studies were included. Strategies and contextual factors that enable patient engagement were thematically grouped and related to techniques to enhance design, recruitment, involvement and leadership action, and those aimed to creating a receptive context. Reported outcomes ranged from educational or tool development and informed policy or planning documents (discrete products) to enhanced care processes or service delivery and governance (care process or structural outcomes). The level of engagement appears to influence the outcomes of service redesign-discrete products largely derived from low-level engagement (consultative unidirectional feedback)-whereas care process or structural outcomes mainly derived from high-level engagement (co-design or partnership strategies). A minority of studies formally evaluated patients' experiences of the engagement process (n = 12; 25%). While most experiences were positive-increased self-esteem, feeling empowered, or independent-some patients sought greater involvement and felt that their involvement was important but tokenistic, especially when their requests were denied or decisions had already been made.

3.1 SDLC (Umbrella Model): the goals identified in the high-level requirements section of the project plan. Each goal will be refined into a set of one or more requirements. These requirements define the major functions of the intended application, define operational data areas and reference data areas, and define the initial data entities

Stages in SDLC. Requirement Gathering , Analysis , Designing , Coding , Testing , Maintenance

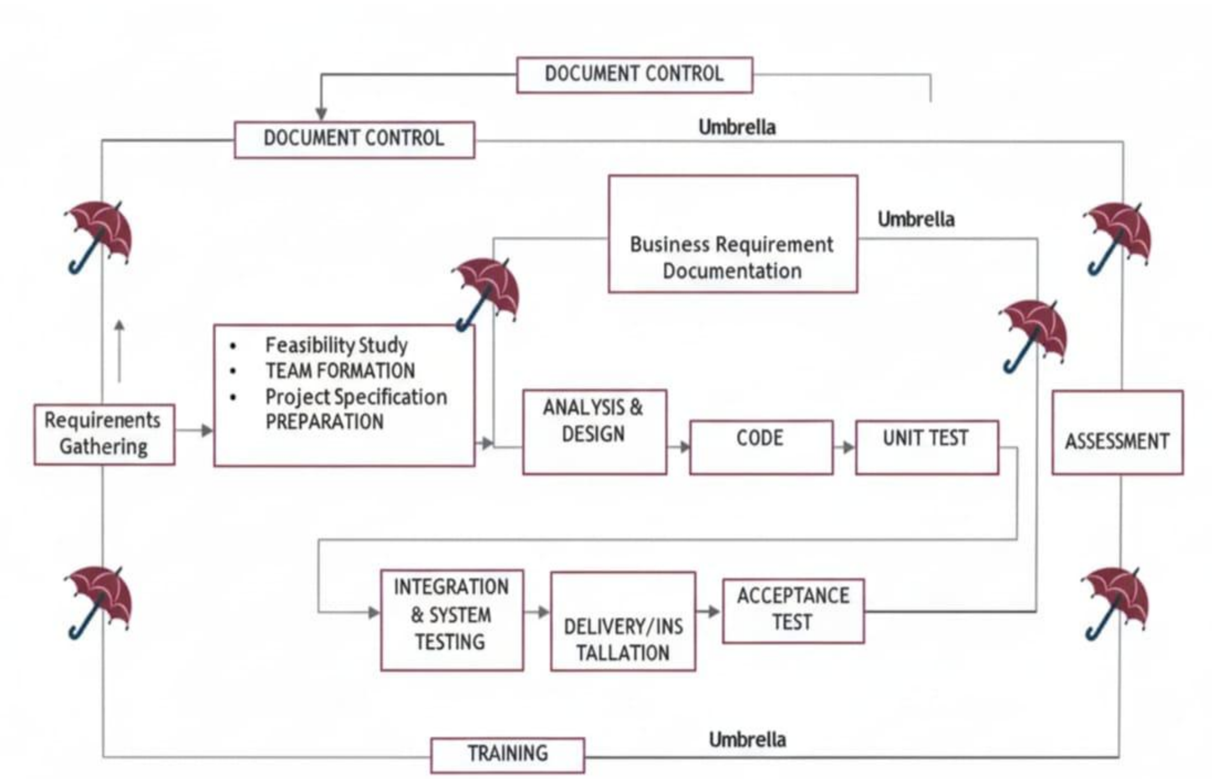

Fig 3.1 SDLC umbrella model

Requirements Gathering stage: the goals identified in the high-level requirements section of the project plan. Each goal will be refined into a set of one or more requirements. These requirements define the major functions of the intended application, define operational data areas and reference data areas, and define 10 the initial data entities. Major functions include critical processes to be managed, as well as mission critical inputs, outputs and reports.
Analysis Stage: The planning stage establishes a bird's eye view of the intended software product, and uses this to establish the basic project structure, evaluate feasibility and risks associated with the project, and describe appropriate management and technical approaches

Designing Stage: The design stage takes as its initial input the requirements identified in the approved requirements document. For each requirement, a set of one or more design elements will be produced as a result of interviews, workshops, and/or prototype efforts. Design elements describe the desired software features in detail, and generally include functional hierarchy diagrams, screen layout diagrams, tables of business rules, business process diagrams, pseudocode, and a complete entity-relationship diagram with a full data dictionary.
Development (Coding) Stage: The development stage takes as its primary input the design elements described in the approved design document. For each design element, a set of one or more software artifacts will be produced. Software artifacts include but are not limited to menus, dialogs, and data 13 management forms, data reporting formats, and specialized procedures and functions.

3.2 Use case Diagram

A use case diagram at its simplest is a representation of a user's interaction with the system and depicting the specifications of a use case. A use case diagram can portray the different types of users of a system and the various ways that they interact with the system. This type of diagram is typically used in conjunction with the textual use case and will often be accompanied by other types of diagrams as well.

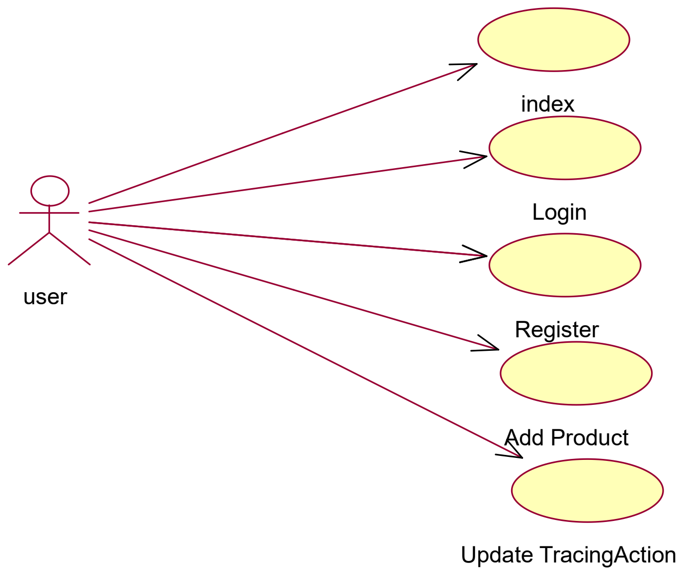

Fig 3.2 Use case diagram

3.3 Use class diagram.

The class diagram is the main building block of object oriented modeling. It is used both for general conceptual modeling of the systematic of the application, and for detailed modeling translating the models into programming code. Class diagrams can also be used for data modeling. The classes in a class diagram represent both the main objects, interactions in the application and the classes to be programmed. In the diagram, classes are represented with boxes which contain three parts, The upper part holds the name of the class, The middle part contains the attributes of the class, The bottom part gives the methods or operations the class can take or undertake

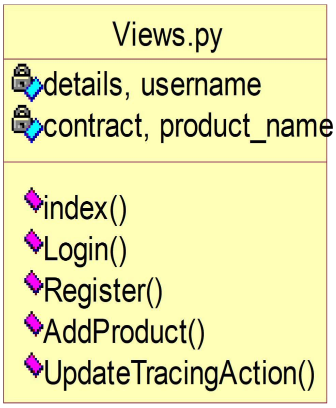

Fig 3.3 use class

3.4 Sequence Diagram.

A sequence diagram is a kind of interaction diagram that shows how processes operate with one another and in what order. It is a construct of a Message Sequence Chart. A sequence diagram shows object interactions arranged in time sequence. It depicts the objects and classes involved in the scenario and the sequence of messages exchanged between the objects needed to carry out the functionality of the scenario. Sequence diagrams are typically associated with use case realizations in the Logical View of the system under development. Sequence diagrams are sometimes called event diagrams, event scenarios, and timing diagrams.

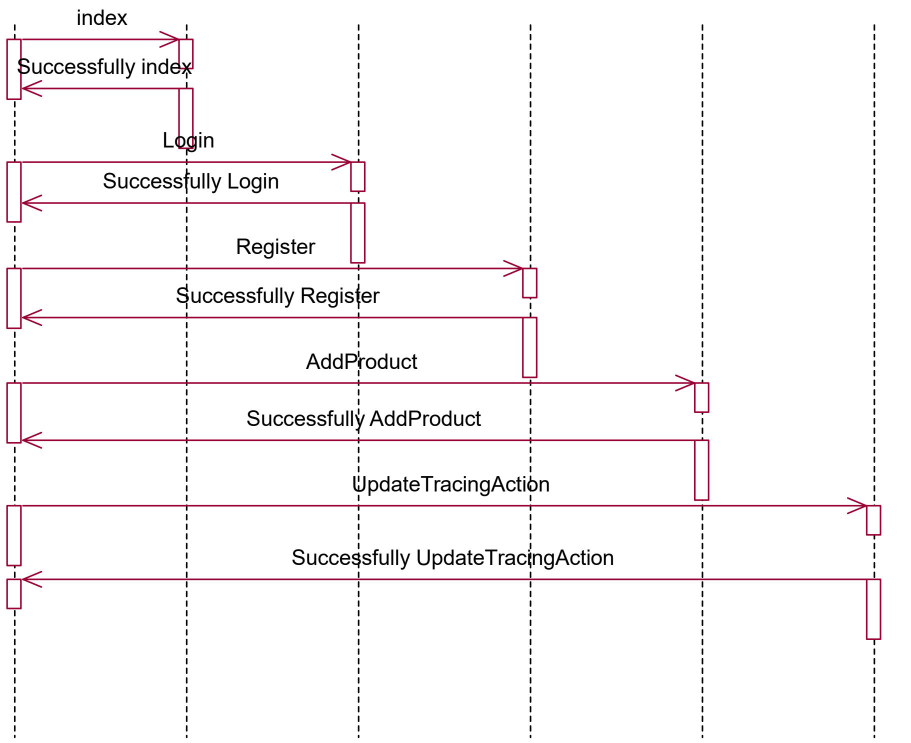

Fig 3.4 Sequence diagram

3.5 Collaboration diagram.

A collaboration diagram describes interactions among objects in terms of sequenced messages. Collaboration diagrams represent a combination of information taken from class, sequence, and use case diagrams describing both the static structure and dynamic behaviour of a system.

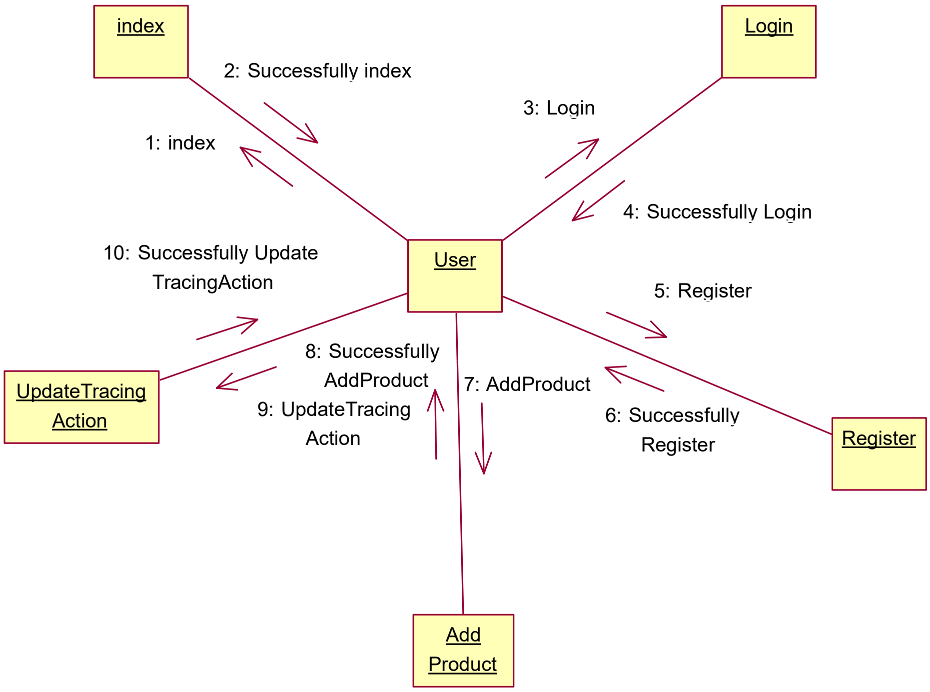

Fig 3.5 collaboration diagram

4 Implementation.

4.1 PYTHON. One of the most popular languages is Python. Guido van Rossum released this language in 1991. Python is available on the Mac, Windows, and Raspberry Pi operating systems. The syntax of Python is simple and identical to that of English. When compared to Python, it was seen that the other language requires a few extra lines.

It is an interpreter-based language because code may be run line by line after it has been written. This implies that rapid prototyping is possible across all platforms. Python is a big language with a free, binary-distributed interpreter standard library .It is inferior to maintenance that is conducted and is straightforward to learn. It is an object oriented, interpreted programming language. It supports several different programming paradigms in addition to object-oriented programming, including functional and procedural programming.it supports several different programming paradigms in addition to object oriented programming, including practical and procedural programming. Python is mighty while maintaining a relatively straightforward syntax. Classes, highly dynamic data types, modules, and exceptions are covered. Python can also be utilised by programmes that require programmable interfaces as an external language.

Here are some key features and characteristics of Python: Readability: Python emphasizes code readability with its clean and intuitive syntax. It uses indentation and whitespace to structure code blocks, making it easy to understand and maintain. Easy to Learn: Python's simplicity and readability make it an excellent choice for beginners. Its straightforward syntax and extensive documentation make it accessible for newcomers to programming. Interpreted Language: Python is an interpreted language, meaning that it doesn't need to be compiled before running. The Python interpreter reads and executes the code directly, making the development process faster and more interactive .Cross-platform Compatibility: Python is available for major operating systems like Windows, macOS, and Linux. This cross-platform compatibility allows developers to write code once and run it on different platforms without modifications .Large Standard Library: Python comes with a vast standard library that provides ready to-use modules and functions for various tasks. It covers areas such as file I/O, networking, regular expressions, databases, and more, saving developers time and effort.

4.2 Dataset Description

Dataset description illustrate how data is processed by a system in terms of inputs and outputs. Data flow diagrams can be used to provide a clear representation of any business function. The technique starts with an overall picture of the business and continues by analyzing each of the functional areas of interest. This analysis can be carried out in precisely the level of detail required. The technique exploits a method called top-down expansion to conduct the analysis in a targeted way .As the name suggests, Data Flow Diagram (DFD) is an illustration that explicates the passage of information in a process. A DFD can be easily drawn using simple symbols. Additionally, complicated processes can be easily automated by creating DFDs using easy-to-use, free downloadable diagramming tools. A DFD is a model for constructing and analyzing information processes. DFD illustrates the flow of information in a process depending upon the inputs and outputs. A DFD can also be referred to as a Process Model. A DFD demonstrates business or technical process with the support of the outside data saved, plus the data flowing from the process to another and the end results.

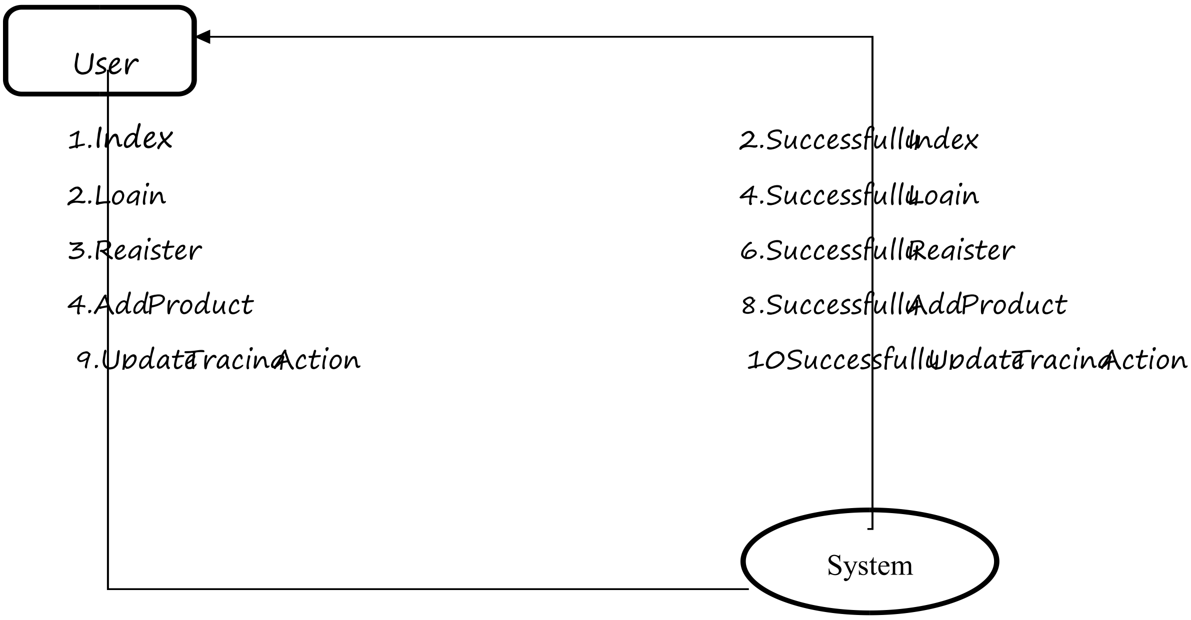

Fig 4.2 dataset description

4.3 Libraries.

In Python, libraries (also referred to as modules or packages) are collections of pre-written code that provide additional functionality and tools to extend the capabilities of the Python language. Libraries contain reusable code that developers can leverage to perform specific tasks without having to write everything from scratch. Python libraries are designed to solve common problems, such as handling data, performing mathematical operations, interacting with databases, working with files, implementing networking protocols, creating graphical user interfaces (GUIs), and much more. They provide ready-to-use functions, classes, and methods that simplify complex operations and save development time.

5. Future Enhancements.

The future of drug traceability in the healthcare supply chain using blockchain technology is both expansive and transformative. As the healthcare industry continues to evolve, the adoption of blockchain is expected to play a central role in ensuring greater transparency, accountability, and safety in pharmaceutical distribution. One promising direction is the integration of blockchain with emerging technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML). These technologies can work in synergy to automate data collection, enhance predictive analytics, and monitor environmental conditions in real time, all while ensuring the immutability and security of records through the blockchain. Moreover, there is a growing need for global standardization and interoperability. As pharmaceutical supply chains often span multiple countries, creating unified protocols and regulations will be essential for seamless cross-border traceability. This also includes the challenge of integrating blockchain platforms with existing legacy systems, which will require innovative solutions and cooperative efforts across the industry, Scalability and energy efficiency remain critical areas of improvement. Current blockchain models, particularly public ones, can be resource-intensive and slow when scaled to meet global supply chain demands. Future developments may focus on optimizing blockchain architectures through more efficient consensus mechanisms and scalable solutions to handle large volumes of data without compromising performance.

6 Result.

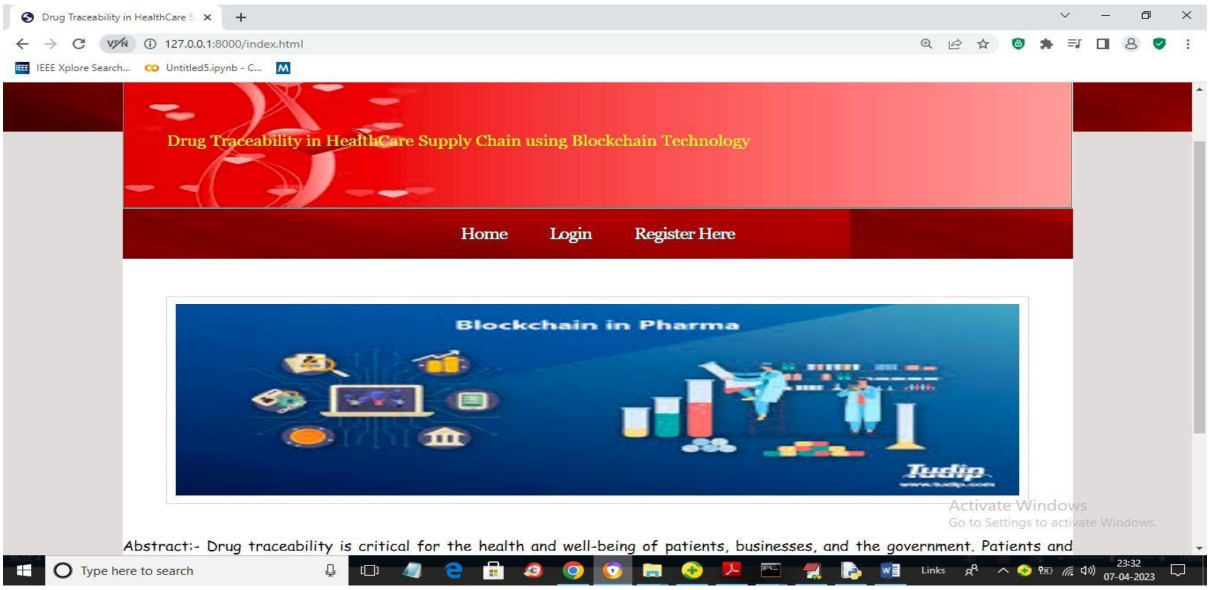

Fig 6.1 In above screen click on 'Login' link and login as admin

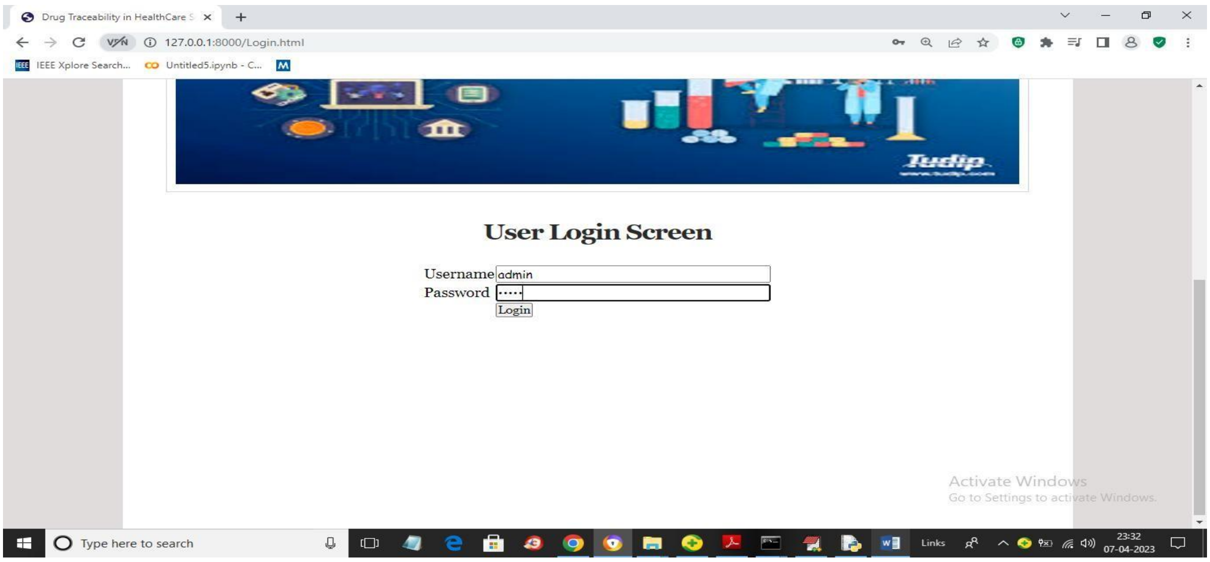

Fig 6.2 In above screen admin is login and after login will get below output

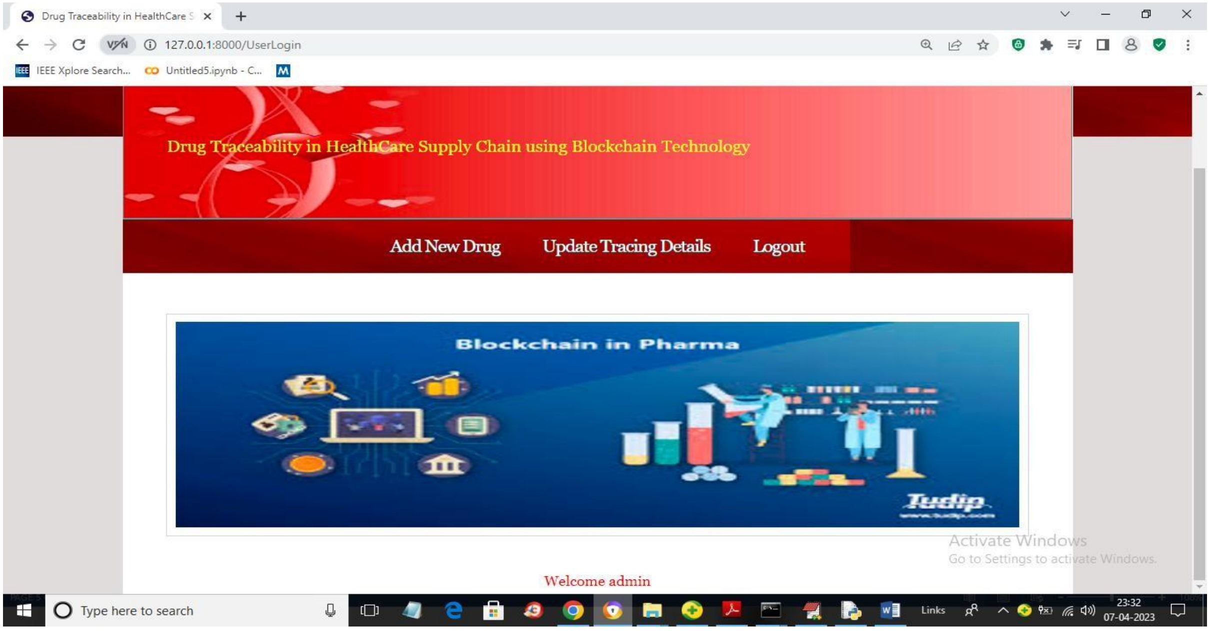

Fig 6.3 In above screen admin can click on 'Add New Drug' link to add new product details

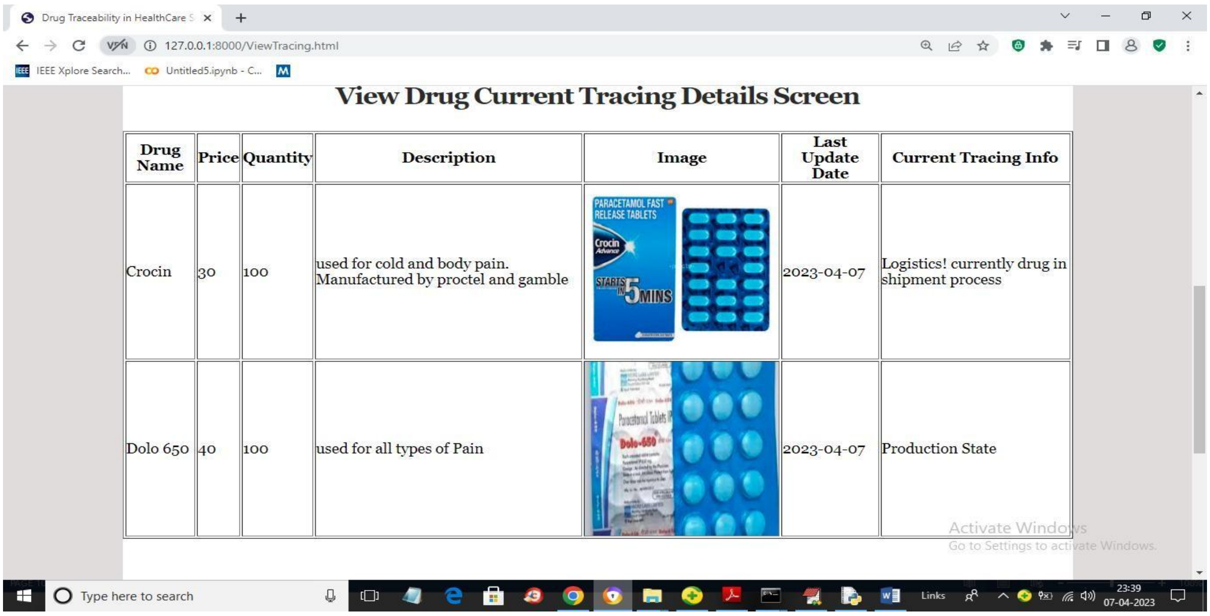

Fig 6.4 In above screen user can view all product details and in last column user can see current tracing data for each Drug. So by using this application any user can know current tracing and manufacture details of any Drug

7 Conclusion.

In conclusion, a blockchain-based supply chain system for drug traceability holds significant promise for enhancing the legitimacy, safety, and overall quality of pharmaceuticals distributed in the global market. The inherent features of blockchain technology—such as decentralization, immutability, and transparency—offer a robust foundation for building an effective and dependable mechanism to track and trace medications throughout the entire supply chain, from the point of manufacture to the end consumer. This capability is especially crucial in the fight against counterfeit drugs, which pose serious risks to public health and undermine confidence in healthcare systems.Such a system could ensure that every transaction or movement of a drug product is securely recorded and visible to authorized stakeholders in real-time. By doing so, it would enhance accountability, reduce fraud, and streamline compliance with regulatory standards across different jurisdictions. However, the successful adoption and implementation of blockchain in drug supply chains is not without its challenges. One of the key obstacles is the coordination and cooperation required among diverse stakeholders—including pharmaceutical manufacturers, regulatory authorities, logistics providers, wholesalers, and healthcare facilities. Building trust and consensus among these parties, many of whom may have differing technological capabilities and business priorities, is essential. Furthermore, integrating blockchain with existing legacy systems and ensuring interoperability across different platforms and standards remain significant technical hurdles. Equally important is the development of secure, standardized, and verifiable methods for data entry. Since blockchain can only ensure the integrity of data once it is entered, the quality and accuracy of the initial data inputs are critical.

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