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Blockchain Based Approach for Drug Traceability in Healthcare Supply Chain

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ABSTRACT: Healthcare supply chains are complex structures spanning across multiple organizational and geographical boundaries, providing critical backbone to services vital for everyday life. The inherent complexity of such systems can introduce impurities including inaccurate information, lack of transparency and limited data provenance. Counterfeit drugs is one consequence of such limitations within existing supply chains which not only has serious adverse impact on human health but also causes severe economic loss to the healthcare industry.

Consequently, existing studies have emphasized the need for a robust, end to- end track and trace system for pharmaceutical supply chains. Therein, an end-to-end product tracking system across the pharmaceutical supply chain is paramount to ensuring product safety and eliminating counterfeits. Most existing track and trace systems are centralized leading to data privacy, transparency and authenticity issues in healthcare supply chains.

In this paper, we present an Ethereum blockchain-based approach leveraging smart contracts and decentralized off-chain storage for efficient product traceability in the healthcare supply chain. The smart contract guarantees data provenance, eliminates the need for intermediaries and provides a secure, immutable history of transactions to all stakeholders. We present the system architecture and detailed algorithms that govern the working principles of our proposed solution. We perform testing and validation, and present cost and security analysis of the system to evaluate its effectiveness to enhance traceability within pharmaceutical supply chains.

KEYWORDS: Healthcare supply chain, blockchain, smart contracts, traceability, pharmaceuticals, counterfeit drugs, data provenance, decentralization.

I. INTRODUCTION

Healthcare supply chain is a complex network of several independent entities that include raw material suppliers, manufacturer, distributor, pharmacies, hospitals and patients. Tracking supplies through this network is non-trivial due to several factors including lack of information, centralized control and competing behaviour among stakeholders. Such complexity not only results in in-efficiencies such as those highlighted through COVID-19 pandemic [1] but can also aggravate the challenge of mitigating against counterfeit drugs as these can easily permeate the healthcare supply chain. Counterfeit drugs are products deliberately and fraudulently produced and/or mislabeled with respect to identity and/or source to make it appear to be a genuine product [2] [3]. Such drugs can include medications that contain no active pharmaceutical ingredient (API), an incorrect amount of API, an inferior-quality API, a wrong API, contaminants, or repackaged expired products. Some counterfeit medications may even be incorrectly formulated and produced in substandard conditions [4].

According to the Health Research Funding Organization, up to 30% of the drugs sold in developing countries are counterfeit. Further, a recent study by World Health Organization (WHO) indicated counterfeit drugs as one of the major causes of deaths in developing countries, and in most case the victims are children [7] [8]. In addition to the adverse impact on human lives, counterfeit drugs also cause significant economic loss to the pharmaceutical industry. In this respect, the annual economic loss to the US pharmaceutical industry due to counterfeit medicine is estimated around $200 billion [9] [10].

II. RELATED WORK

The related work section in the paper would typically discuss previous research, projects, or initiatives that have addressed similar challenges in healthcare supply chains or have utilized blockchain technology for traceability and transparency. Some potential topics that could be covered in the related work section include:

1. Previous studies on healthcare supply chain management and the challenges associated with traceability and counterfeit drugs.

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2. Existing blockchain-based solutions for supply chain management in various industries, including pharmaceuticals.
3. Research on smart contracts and decentralized storage systems in the context of supply chain traceability.
4. Case studies or pilot projects that have implemented blockchain technology for improving transparency and traceability in healthcare or pharmaceutical supply chains.
5. Comparative analyses of different blockchain platforms and their suitability for healthcare supply chain applications.
6. Regulatory frameworks and standards related to traceability and authenticity in pharmaceutical supply chains, and how blockchain technology aligns with these requirements.
These references would provide context for the proposed Ethereum blockchain-based solution and highlight its novelty, advantages, and potential contributions to the existing body of knowledge in this field.

III. EXISTING METHOD

Traceability is defined as the ability to access any or all information relating to the object under consideration, throughout its life cycle, by means of recorded identifications. The object under consideration is referred to as Traceable Resource Unit (TRU) which is any traceable object within the supply chain. Traceability objectives are twofold; to track the history of transactions, and to track the real-time position of the TRU. In this context, a traceability system requires access to information related to the drug which is the TRU in the supply chain by using different identification techniques to record its identity and distinguish it from other TRUs. The components of a traceability system can be broadly identified by a mechanism for identifying TRUs, a mechanism for documenting the connections between TRUs, and a mechanism for recording the attributes of the TRUs.

Existing solutions within supply chain management have traditionally used barcodes and RFID tags as identification techniques, Wireless Sensor Networks (WSN) to capture data, and Electronic Product Code (EPC) to identify, capture, and share product information to facilitate tracking of goods through different stages [22] . In this context, Smart-Track [23] utilizes GS1 standards barcodes containing unique serialized product identifier, Lot production and expiration dates.

The information contained in the GS1 barcode is captured across various supply chain processes and used to maintain a continuous log of ownership transfers. As each stakeholder records the possession of the product, an end user (patient) can verify authenticity through central data repository maintained as Global Data Synchronization Network (GDSN) by using a smart phone app. In the downstream supply chain at the warehouse, pharmacy and hospital units can scan the barcode to verify the product and its characteristics. Similarly, Data-Matrix tracking system [24] creates a Data-Matrix for each drug which includes the manufacturer ID, Product ID, Unique ID of the package, the authentication code, and an optional meta-data. This allows the patient to verify the origin of the drug by using the attached Data-Matrix.

IV. PROPOSED METHOD

The proposed system implements which approaches identifies and engages major stakeholders in the drug supply chain i.e. the FDA, supplier, manufacturer, distributor, pharmacy, and patient, whereas [20] is limited to the supplier, manufacturer, and wholesaler as the stakeholders. Consequently, the pharmacists are represented as an external entity which is not the case in a real drug supply chain.

Secondly, we make explicit efforts to identify and define relationships among stakeholders, on-chain resources, smart contracts, and decentralized storage systems which is lacking in [20]. Furthermore, in view of the significance of interactions among stakeholders, we have included precise definitions to remove any ambiguity, whereas such interactions have not been defined as part of [20].

Thirdly, we use the smart contracts technology to achieve real-time, seamless traceability with push notifications so as to minimize human intervention and therefore undesired delays. Specifically, each drug Lot is assigned a unique smart contract that generates an event whenever a change in ownership occurs and a list of events is delivered to the DApp user. However, the smart contracts in [20] are programmed for specific roles such as supplier, manufacturer, and wholesaler which requires each participant to manually confirm which drugs are received. Such approach can introduce delays and inaccuracies in the immutable data stored on the ledger.

Finally, we have conducted a cost and security analysis to evaluate the performance of the proposed solution including discussion on how the proposed solution can be generalized to other supply chains.

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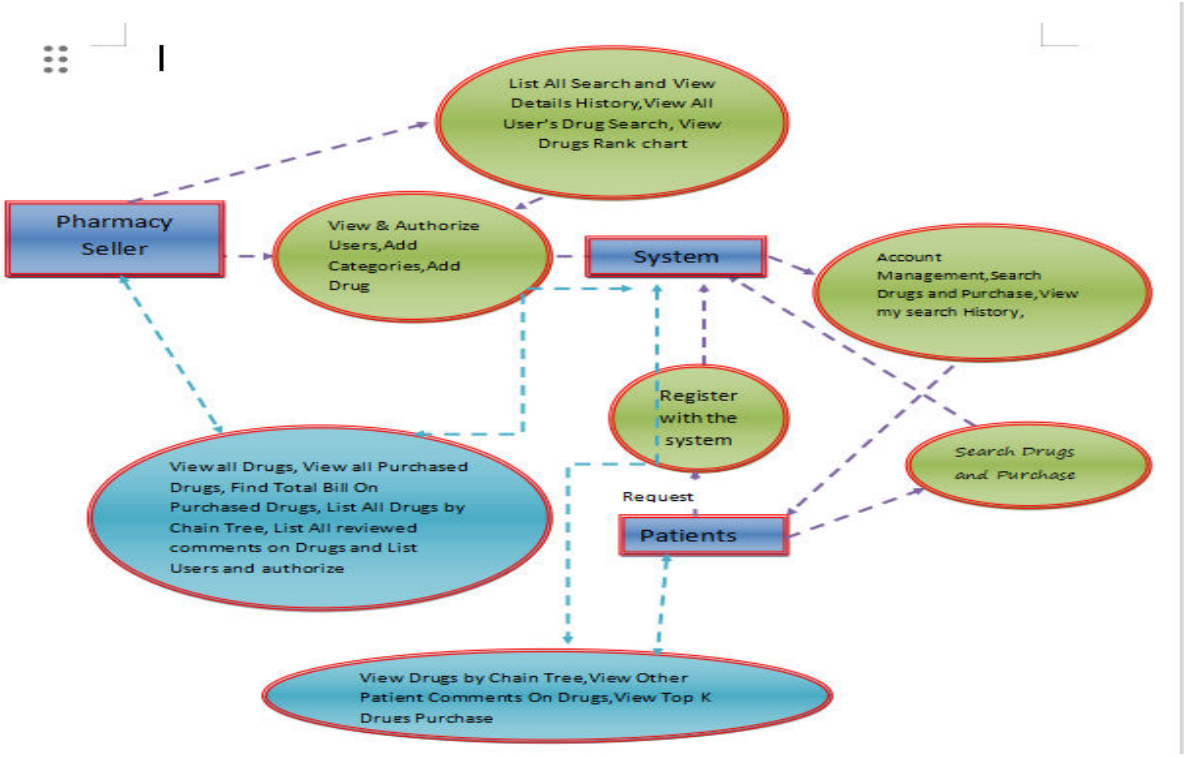
Fig 1: Flow Chart



V. SIMULATION RESULTS

In the simulation results section of the paper, you would typically present the outcomes of testing and validation conducted on the proposed blockchain-based approach for drug traceability in healthcare supply chains. Here's an outline of what you might include:

1. Testing Methodology: Describe the methodology used to conduct the simulation, including any assumptions made and the parameters varied during testing.
2. Performance Metrics: Define the metrics used to evaluate the effectiveness of the blockchain-based approach, such as throughput, latency, scalability, and data integrity.
3. Simulation Environment: Provide details about the simulation environment, including the software tools used, the hardware configuration (if applicable), and any specific settings or configurations.
4. Results Analysis:
   - Throughput: Present the throughput achieved by the system under different conditions, such as varying transaction volumes or network loads.
- Latency: Discuss the latency observed in the system for transaction processing, including any variations based on network conditions or transaction complexity.
   - Scalability: Evaluate the scalability of the proposed approach by analyzing how the system performs as the number of transactions or participants increases.
   - Data Integrity: Assess the integrity of data stored on the blockchain, highlighting the immutability and transparency provided by the system.
   - Cost Analysis: Provide insights into the cost implications of implementing and operating the blockchain-based solution compared to traditional approaches, considering factors such as infrastructure costs, transaction fees, and operational overhead.
5. Comparison with Existing Solutions: Compare the performance and capabilities of the proposed blockchain-based approach with existing solutions or alternative technologies, highlighting its advantages and potential areas for improvement.
6. Discussion of Findings: Interpret the simulation results in the context of the objectives of the study, discussing how the proposed approach addresses the challenges identified in healthcare supply chains and its potential impact on improving traceability and transparency.

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7. Limitations and Future Work: Acknowledge any limitations or constraints encountered during the simulation, and propose avenues for future research to further enhance the proposed blockchain-based approach or address remaining challenges.

By presenting comprehensive simulation results, you can provide readers with valuable insights into the feasibility, effectiveness, and practical implications of implementing the blockchain-based solution for drug traceability in healthcare supply chains.

Fig 2.1: Home Page

Fig :2.2 :Hospital login page

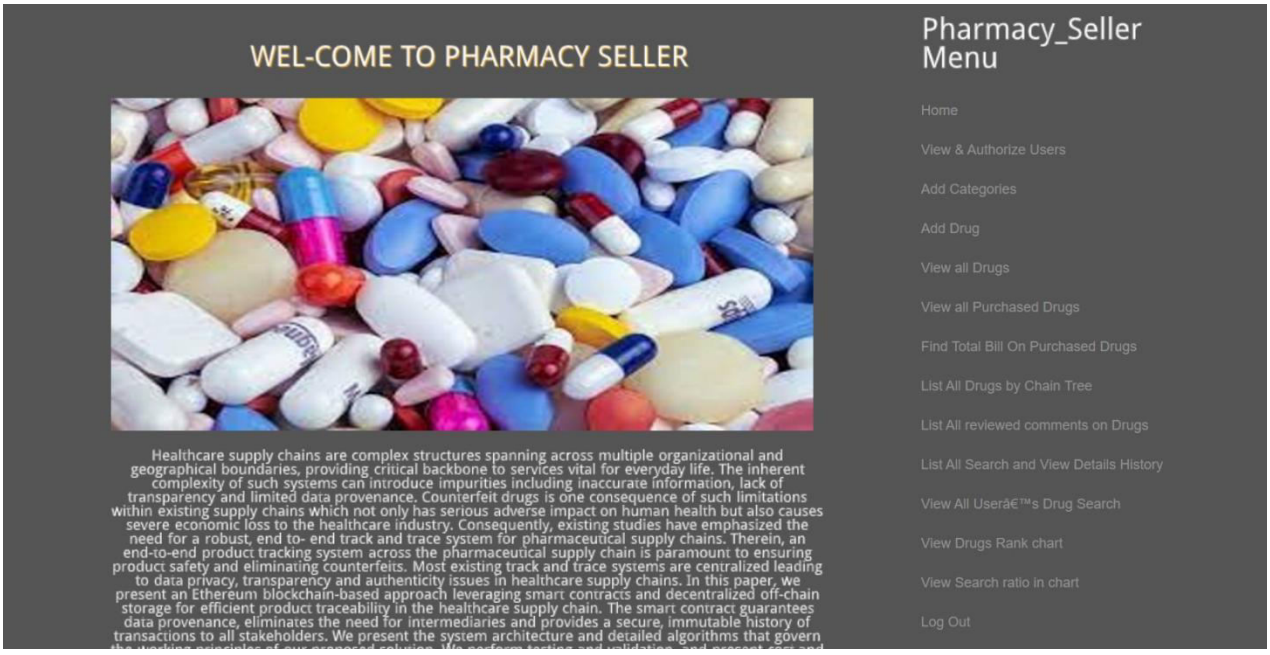

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Fig:2.3:Hospital main menu

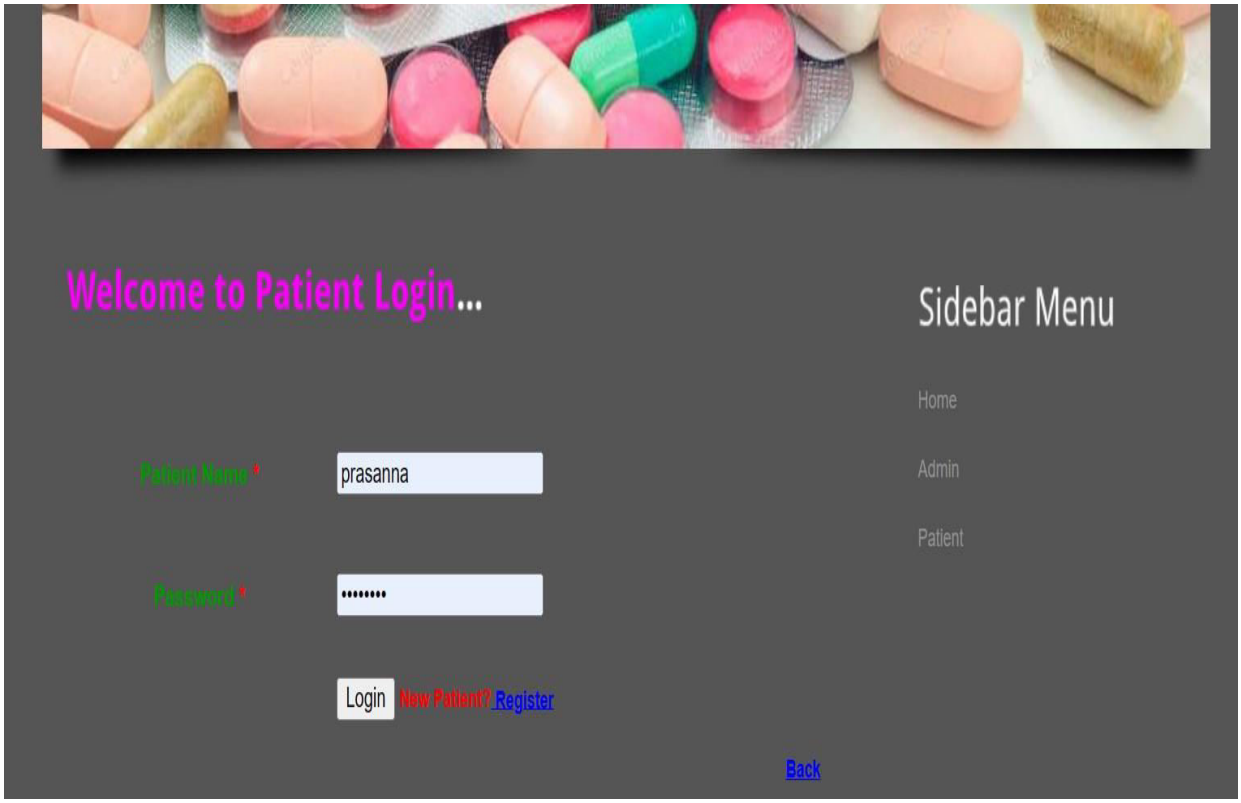

Fig:2.4: Patient Login Page

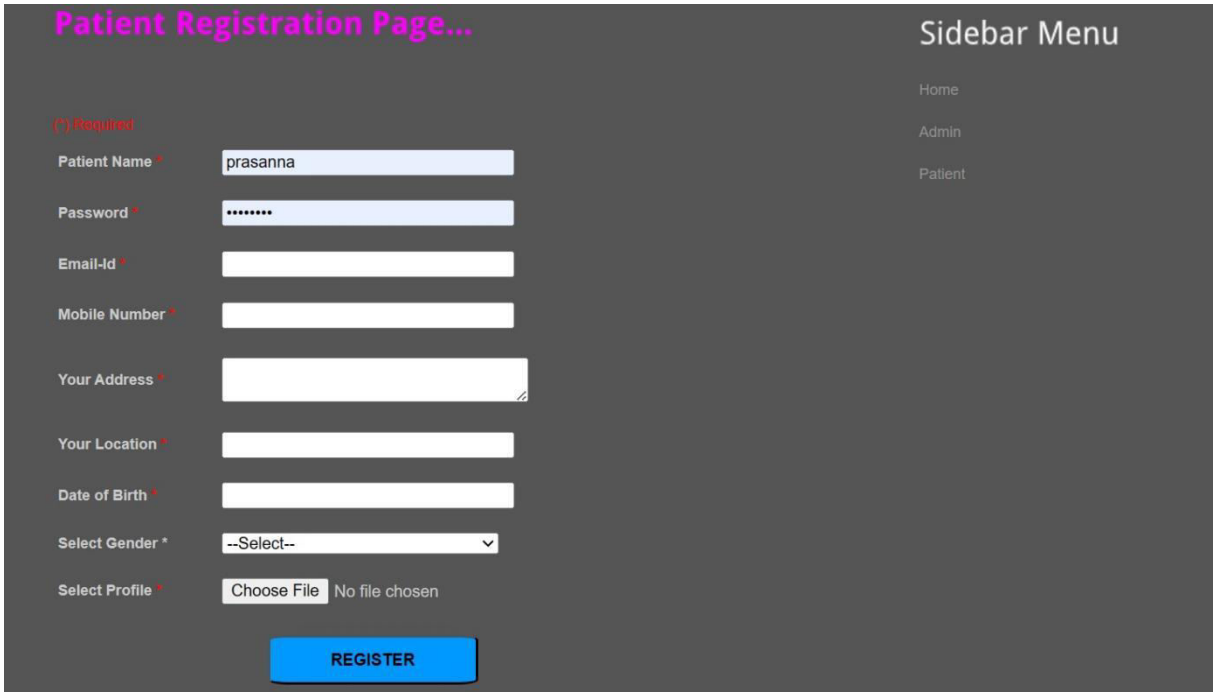

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Fig :2.6 : Donor Details

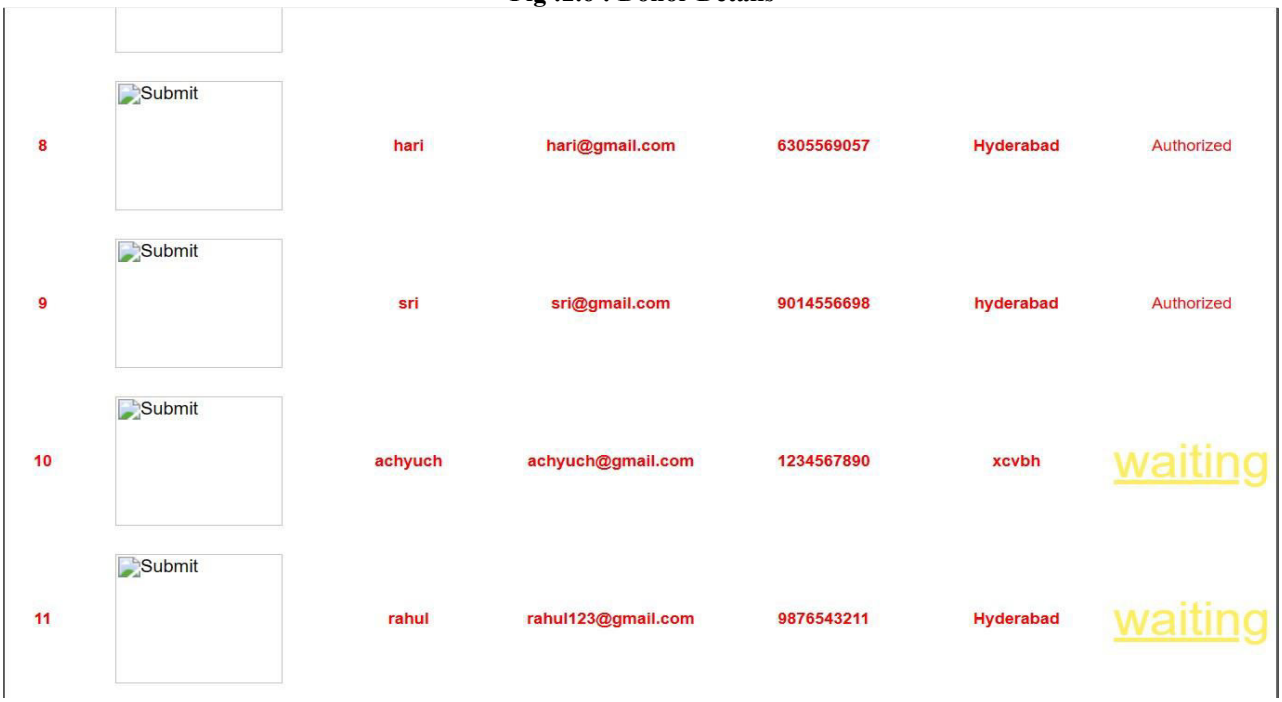
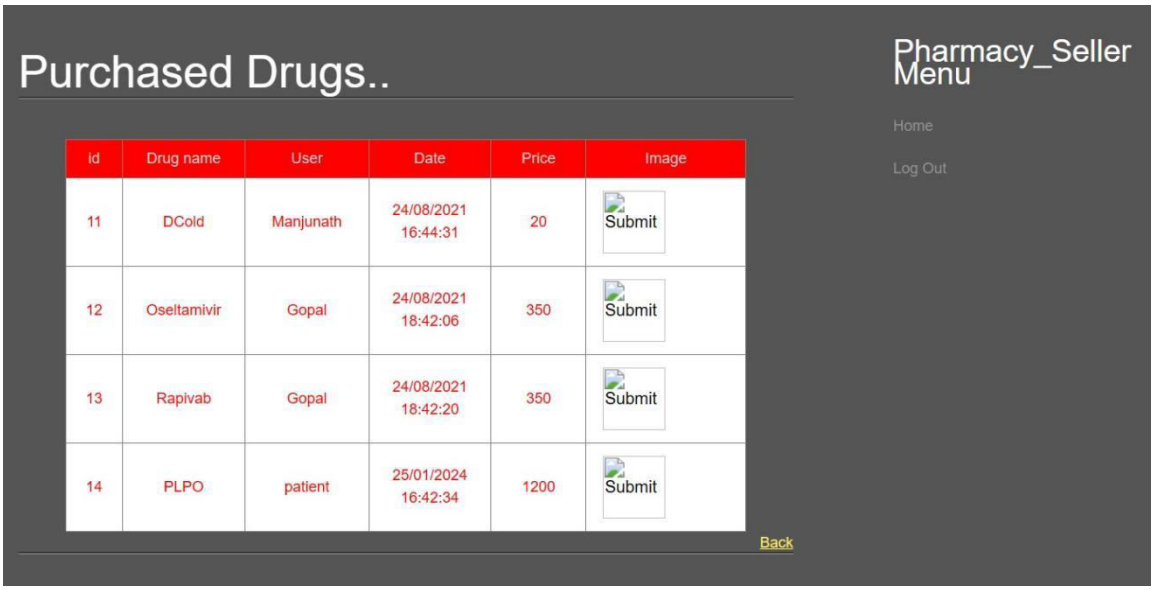


Fig 2.7: Purchased Drugs:



VI. CONCLUSION AND FUTURE WORK

In this paper, we have investigated the challenge of drug traceability within pharmaceutical supply chains highlighting its significance especially to protect against counterfeit drugs. We have developed and evaluated a blockchain-based solution for the pharmaceutical supply chain to track and trace drugs in a decentralized manner. Specifically, our proposed solution leverages cryptographic fundamentals underlying block chain technology to achieve tamper-proof logs of events within the supply chain and utilizes smart contracts within Ethereum block chain to achieve automated recording of events that are accessible to all participating stakeholders.

We have demonstrated that our proposed solution is cost efficient in terms of the amount of gas spent in executing the different functions that are triggered within the smart contract. Moreover, the conducted security analysis has shown

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that our proposed solution achieves protection against malicious attempts targeting is integrity, availability and nonrepudiation of transaction data which is critical in a complex multi-party settings such as the pharmaceutical supply chain.

We continue our efforts to enhance the efficiency of pharmaceutical supply chains and envision to focus on extending the proposed system to achieve end to end transparency and verifiability of drugs use as future work.

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