Detecting Fake Drugs using Blockchain

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ABSTRACT

The existing supply chain for the pharmaceutical industry is obsolete and lacks clear visibility over the entire system. Moreover, the circulation of counterfeit drugs in the market has increased over the years. According to the WHO report, around 10.5% of the medicinal drugs in lower / middle income countries are fake and such drugs may pose serious threats to public health, sometimes leading to death. Keeping these threats in mind, in this paper, we propose a blockchain based model to track the movement of drugs from the industry to the patient and to minimize the chances of a drug being counterfeit. The reasons for using blockchain technology in our work include its immutability property and easy tracking of an entity in the blockchain. Through this proposed model, the manufacturer would be able to upload the details corresponding to a drug, after which it will be sent for approval to the Government. Thereafter, hospitals and pharmacies, based upon their requirements, can request the approved drugs. In the future, if a patient wants some medication, then he or she has to request it on the blockchain network. The request will be sent to the nearest hospital/pharmacy and thereafter, the patient can collect the medication. To implement this model, we have used Hyperledger fabric due to the presence of many auto implemented features in it. Our implementation of the proposed blockchain based model highlights that the model can successfully detect any drug being counterfeit. This will be beneficial for the users getting affected with counterfeit drugs. Moreover, with the proposed model, we can also track the movement of the drug beginning from the manufacturer right up to the patient consuming that drug.

KEYWORDS: *Blockchain, Counterfeit Drugs, Drugs Tracking, Fake Medicines, Health Care*

I. INTRODUCTION

In this era, the world of piracy and counterfeiting has touched nearly every product including medicines and drugs. The challenge of counterfeit drugs in the pharmaceutical industry has been increasing across the globe over the past many years. According to a WHO report [1], around 10.5% of the pharmaceutical drugs in the markets of low or middle-income countries are fake. Hence, there is a need to develop a strong model to overcome the issue of counterfeiting drugs. Moreover, the current industry lacks clear visibility over the delivery of the drugs from the pharmaceutical company to the patients. Keeping these challenges in mind, we aim to develop a blockchain-based model that can prevent drug counterfeiting and keep track of drug movement from the industry to the patients.

Contributions: Such a problem of counterfeiting drugs and their tracking can be solved by applying QR codes on them during their manufacturing process. Thereafter, we can track their journey by scanning their QR codes. However, because one can make a copy of the QR code and this copied code can be applied to the counterfeit drug, this solution will not completely solve the problem of drugs tracking and counterfeiting. Hence, we came up with a model based on a decentralized system such as blockchain, using Hyperledger fabric, in which the manufacturer will create a drug and will upload the details on this blockchain. After that, the Government will approve these drugs. Thereafter, hospitals and pharmacies can request the available approved drugs as per their requirements. In the future, if any patient wants some

medication, then he or she has to request it on the blockchain network, and then the request will be sent to the nearest hospital/pharmacy and after that, the patient can collect the required drugs. The main advantage of using such a blockchain network is that drug tracking is easy as the drug is visible on the network at every stage. Moreover, because this blockchain network is closed, no one from the outside can fraud the drugs.

Organization: The rest of the paper is structured as follows. We review the related works in the field of blockchain and the healthcare industry in Section 2. We discuss the proposed blockchain-based model in detail in Section 3, and we conclude in Section 4.

II. RELATED WORK

In this section, we review the related work in the field of healthcare and blockchain. We further divide this section into two subsections: 1. Blockchain-related works, and 2. Blockchain Applied in the healthcare field.

A. Blockchain Related Works

First, what we have done is, review the works that have discussed blockchain network various use cases. The study conducted in [2] proposed an approach based on a decentralized solution which is blockchain to creating a DT (Digital Twin) which ensured the data traceability, data authenticity, and immutability of information. They utilized the decentralized IPFS stockpiling workers to store the information identified with DT.

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It is very convenient if one can remotely control IOT devices but it comes with the cost of data exploitation. Lin et al. [3] designed a secure and efficient remote user confirmation system based on a blockchain model. They incorporated this decentralized method, group benchmark, and subject matter validation to give solid evaluation of the user's entrance history.

Parking vehicles in big cities can be a big challenge. Many savvy parking applications tend to solve these problems however, a large number people experience the ill effects of protection issues or they work in a centralized environment. Zhang et al. [4] proposed smart parking based on a decentralized approach which was reliable and the privacy was protected. Using the concept of smart contracts, they were able to accomplish fairness. The writer in [7] made a singular assent working model for the information sharing stages identified with wellbeing. Through this model, they successfully managed the accountability of all the members in the information sharing stages. This model also makes sure that a person's will is

kept on priority. Autonomous vehicles can sense and navigate in their environment without the interference of human hands. But in case of road accidents, mishap legal sciences must decide the obligations. The authors in [8] made an instrument of verification of occasion with a dynamic alliance agreement to accomplish undeniable mishap crime scene investigation by generating trustworthy data. The most challenging aspect in conducting elections is to gain the faith of all the electors in the counting cycle. Yang et al. [9] proposed a protocol for election which is based on decentralized approach i.e. blockchain-technology. Their model does not need a committee to count the votes. They successfully created an encryption system that guarantees that no one can decode the votes but each one of us can ensure the legitimacy of the votes. Yuan et al. [10] directed a study based on blockchain Intelligent Transportation Systems (ITS). They introduced a contextual investigation for blockchain based on going ride sharing services.

B. Blockchain for Healthcare and Drugs

In this subsection, we discuss the works that have applied blockchain in any aspect of the medical industry. The authors in [14] highlighted various use cases of blockchain in the medical industry such as research on users that are on medication and management of the health sector. In this report, they mentioned strategies to remove middlemen in the medical sector and also highlighted the new way of doing medical transactions. McGhin et al. [15] addressed the future research side of the medical sector. They also addressed some of the unique requirements that are not addressed in earlier conducted blockchain experiments. Apart from that, they addressed research areas like scalability, block withholding attack, and blockchain mining incentives in which blockchain might lack for the healthcare sector. Siyal et al. [17] reviewed the work that is already existed in the medical sector. They also highlighted the recent research in this sector that is using a decentralized model such as blockchain. They highlighted the usability of a decentralized model for neural system. They have successfully stored a virtual digital brain on the decentralized network like blockchain. They also highlighted some impactful factors that are creating hurdles of the blockchain in the medical sector. Every blockchain based model runs according to the smart contract. Kumar et al. [20] designed the same for the medical industry. Apart from that, they highlighted various challenges of blockchain for healthcare such as scalability restrictions, high development cost, standardization challenges, cultural resistance, regulatory uncertainty, etc.

Bell et al. [21] addressed the issues existing in the current healthcare field. They also highlighted fields in the healthcare system where blockchain can solve various problems. Some of those fields are Clinical Trials, Data Sharing between many entities (such as hospitals, manufacturers), Patient Records, etc. They also mentioned that the resistance of this system to adopt blockchain in their supply chain is the biggest reason for not using blockchain in healthcare. The authors in [22] addressed the use cases of blockchain and reviewed, assessed various publications and consequently proposed a methodology which is to integrate blockchain with the processes involved in the current healthcare system. They found that EHR (Electronic Health Records) and PHR (Personal Health Records) are the areas where blockchain is mainly used and Ethereum and Hyperledger fabric are the most preferred open-source frameworks for developing a blockchain based application. The authors in [23] highlighted the privacy related to data stores and the data sharing platforms. They used a permissioned blockchain to ensure the vulnerabilities are removed corresponding to data transfer and since the system is decentralized it also ensures the issue of single point of failure is resolved. They also developed a mobile application which collects user's data through the means of manual input and medical devices. Dwivedi et al. [24] pointed out the issues related with privacy and security associated with data sharing and storing. They used blockchain to ensure secure handling of data within the network. They also tried to solve the problems associated with integrating blockchain with IoT devices and proposed a new structure of blockchain that can be integrated with IoT devices.

The authors in [33] highlighted the issue regarding drug safety and tried to solve the same issue using Blockchain technology which was integrated with QR code. They highlighted the irregularities present in the current supply chain of pharma industries and proposed a methodology that consisted of blockchain-based architecture for the supply chain. Their proposed methodology ensured the reliability aspect of the drug as well as well as the genuineness of the involved manufacturer. Haq et al. [34] specified the problems that are present in the current pharma supply chain and explained how blockchain can be used instead of the current supply chain to ensure traceability and transparency while transferring a particular entity from one level to another. They suggested a permissioned blockchain for storing all the data involved within the network and since it is a permissioned blockchain so it ensured that only trusted parties are becoming a part of the network.

The authors in [35] highlighted the use cases of a decentralized model such as blockchain in the medical sector. They discussed the use of blockchain in various fields such as EHR (Electronic Health Records), Medical Insurance, Bio-medical Field and Medical Supply Chain. In conclusion they stated that this technology has still not been adopted by healthcare systems where this is capable of solving various problems. People who are in-charge of making these decisions should become aware of the technology's potential and the revolutionary power that it carries with itself and should introduce it in the current healthcare system.

Debe et al. [36] addressed various issues that can impact the medical supply chain. He also mentioned some reasons for this such as wrong prescribed medicines to patients, ordering of too many medicines. To wipe out the above mentioned issue, they proposed a blockchain solution that can handle the easy return and exchange of medicines that can be used further. In their proposed system, medical stores and customers have power to give the fit drugs to needy one at a lower price. They have used Ethereum for implementing their idea and designed an architecture for the same. Shae et al. [37] proposed an architecture based on blockchain for solving problems such as improper prescription of medicines for patients .They also highlighted various issues such as technical problems on implementing this and shared some insights for solving them. In the paper, the authors briefly talked about the medical sector and described the architecture design, barriers and usability of blockchain in medical sector. Saxena et al. [38] briefly talked about the medical supply chain and highlighted various issues that are making the supply chain worse. They also discussed the current implemented strategy for solving the counterfeiting problem. They had researched with people that are from the medical industry and developed a blockchain based tool "Pharma Crypt" for solving some of the problems.

III. METHODOLOGY AND IMPLEMENTATION

In this section, we explain our proposed blockchain based model for drugs tracking and counterfeiting. We begin our discussion with the introduction to Smart Contracts and after that we discuss the concept of transactions in blockchain. We show how a transaction will execute in blockhain network with diagrammatic representation.
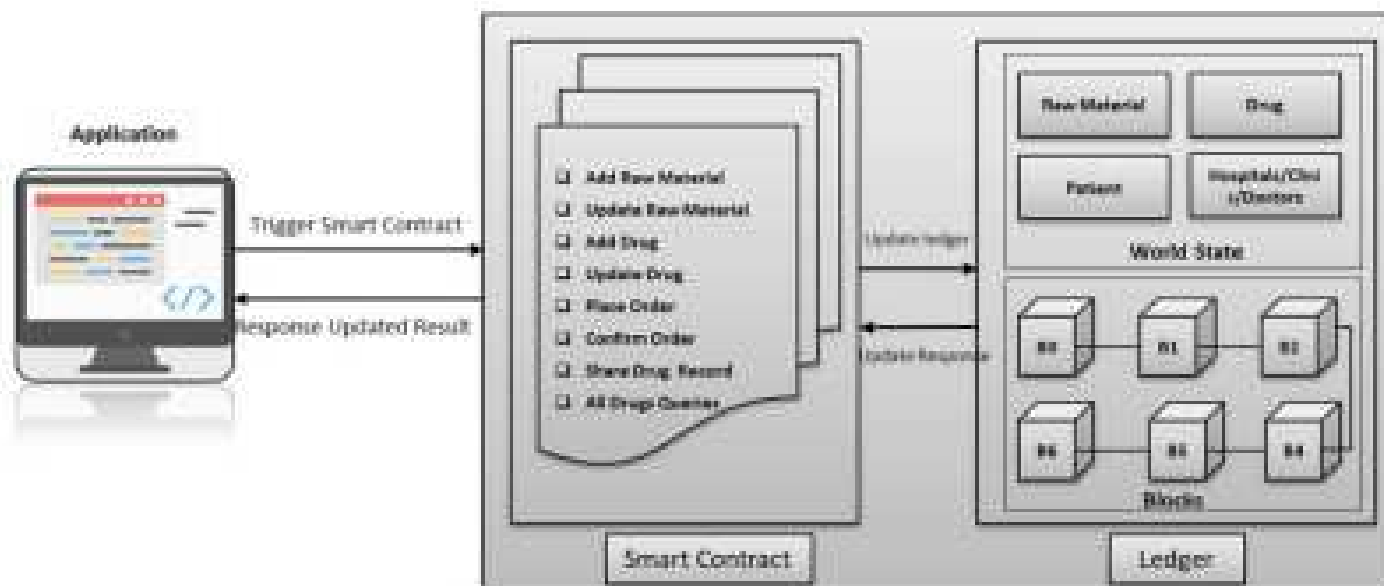
Figure 1: Smart Contract Architecture

A. Smart Contracts

A Smart Contract is a few lines of code which is automatically executed whenever some terms and conditions(that are already set) are satisfied in a blockchain network. It can include the transfer of assets from one level to another or some kind of update in the network.

Basically, it is a piece of code that enforces the agreement done between two parties without paying any amount to a third person. They also enable the users to manage their access rights and their assets among different parties. They are stored on ledgers and are secured from any kind of tampering. The time complexity for the execution of transactions is high because the transactions are executed among all the peer nodes of the network periodically or in sequence. Moreover, the data corresponding to that is written on all the ledgers hence giving rise to space complexity. This issue is addressed in our model by deploying the contracts only for certain nodes of the network and not all the nodes. Hence, some nodes of this network can validate the transactions, and hence space and time complexity is improved. We used Java and Node. JS programming languages for writing smart contracts. The figure 1 represents an overall architecture of smart contract execution for our proposed model.

B. Transactions Execution Procedure

The roadmap for a transaction in the network is summarized in figure 2. Users are shown the front-end of the application where the credentials are required so that the user can enter the blockchain network. Enrollment of all the participants in the network is done by the administrator which gives the credentials along with an enrollment certificate to all the users. After the user has gone through the login process, the user initiates a transaction using his/her credentials. Then the request is sent to all the peer nodes (divided into two sub-categories: committers and endorsers).

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Endorsers execute the transaction if it is valid. Committers validate the result obtained by executing those requests before it is written to the ledger. We can also say that endorsers are similar to committers who hold the predefined smart contract. These endorsers execute the contract of requested transactions in their simulated environment before writing to the ledger. The endorser fetches the read/write data while executing the request in their environment which is RW set. The read in the RW set contains information about the world state before the transaction is executed and the writing part of the RW set contains information about what is written in the world state after the request is executed in the environment. Then endorsers return the executed transaction to the client application along with RW sets. The user again submits the signed transaction with all RW sets to the consensus node. The consensus node sends the transaction to the committers. The committers validate by matching the current world state and if matched then it is written into the ledger. Finally, committers will send an alert message regarding the transaction status. Communication between application and blockchain network is achieved with the help of REST API and SDK.

C. Drug Supply Chain with Hyperledger

Now, we will demonstrate the working of the Drug Supply Chain using Hyperledger fabric. The first step that is involved in this application is to first start the blockchain network. The network consists of the peers, the

ORDERER, and the chain code which is installed on all the peers. The chain code is nothing but the smart contract, which is installed in all the peers. Moving on, we will see how the flow of the application works through a network diagram as shown in figure 4.

Figure 4 summarizes an architectural view of our proposed model. We identified six active peers, i.e., the manufacturer, Government, Drugs Administration Organization (DAO, something similar to FDA), hospital, customer, and the doctor.

We'll now discuss how drug-related information moves in the blockchain to all the peers, starting from the manufacturer and ending at the customer. Suppose the manufacturer creates a drug, and he enters the details of the drugs in the blockchain.
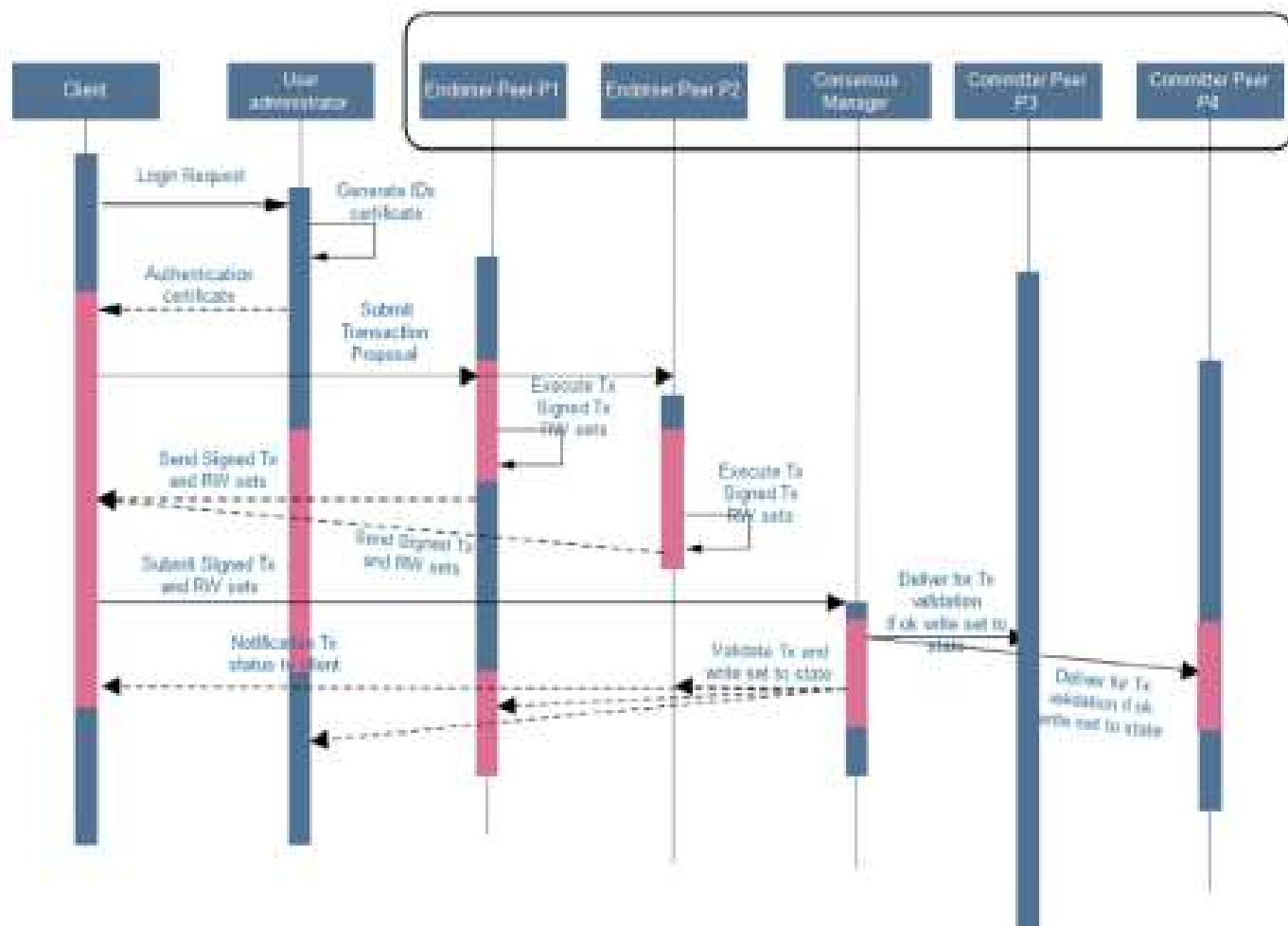

Figure 2: Transaction Execution Procedure

These drugs need to be approved at the government end and the DAO. Say, once the manufacturer enters the drugs, the drug details are added in the blockchain, and it moves to the government, the details are then distributed to all the other peers as well. The government entity will check whether the manufacturer is proper or not, and then approves the drug. The DAO will check whether the quality of the drug is okay and approve the drug. Once both the government and the DAO have approved the drug, it is then moved to the hospital or the pharmacy, where it is clear and safe to the customers and patients and then a customer can purchase it. Once the customer retains a particular drug by inputting what condition he is suffering from, this particular information of the customer and the drug that he has purchased, i.e., the prescription, is then sent to the doctors for approval.

The doctors or the medical professionals, verify that the drug, which is bought by the customer, is prescribed properly, and then approve the purchase. So, once it is approved, the customer is able to purchase that particular drug. This is a flow that starts from the manufacturer who creates the drug and then ends with the customer who purchases the drug. Hence, the drug-related information moves through the blockchain among all the peers. Now that we have shown the blockchain network itself, and the basic flow diagram in Figure 4, we will now see how The entire application works, through the self-designed user interface.

Every peer has to log in through a web page, so we will now log in as the manufacturer. Figure 3 is the sample login page of the manufacturer.

There is a choose file option in which we need to select the manufacturer-specific ID certificate to authorize him and encrypt transactions in the blockchain network.

Figure 3: Manufacturer Login Interface

These certificates are created when the blockchain network itself is started and act as a sort of fingerprint or an ID card to authenticate that particular identity into the blockchain network. These are peers specific certificates and every peer has a unique ID. So, now we are in the drug manufacturer interface. This is where the entire flow starts, as shown in the architecture diagram in Figure 4. In this manufacturer interface, we create the drug details as shown in Figure 5.
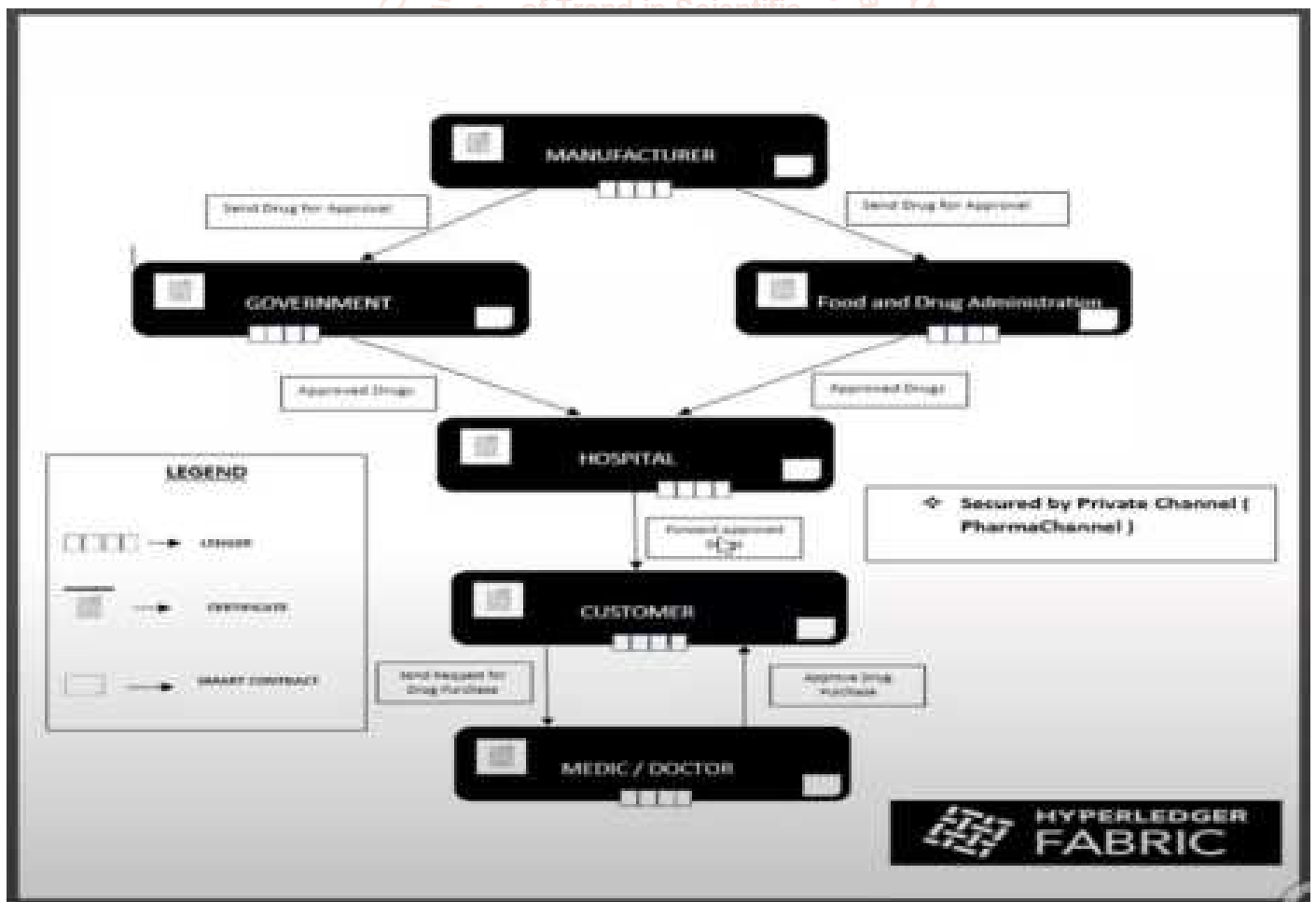

Figure 4: Architectural View of Proposed Model
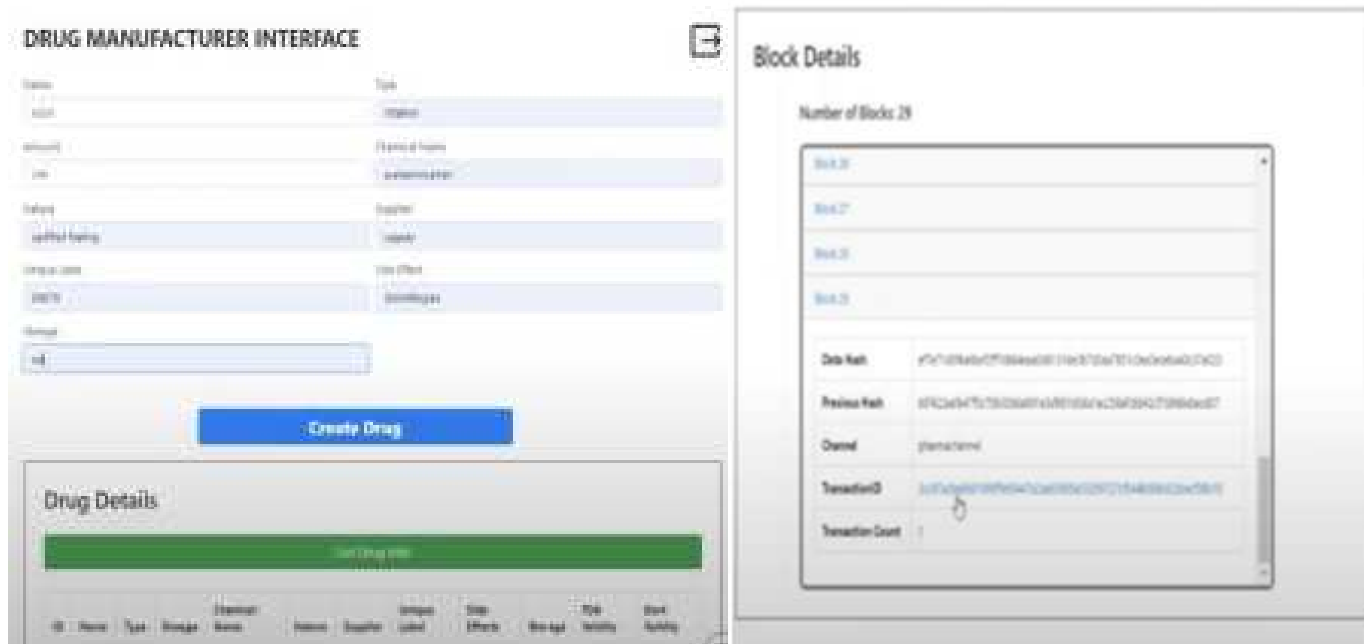
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Figure 5: Drug Manufacturing Interface

We have given the details of a drug to create it in Figure 5. And once we click the button *Create drug*, then we'll have a successful transaction, and the transaction ID will be shown as a notification prompt as shown in Figure 6.

Figure 6: Notification Prompt

It goes like 3cc87. So in every peer interface, we also intend to show the blockchain itself and the number of blocks for transparency, as shown in Figure 7. Whereas, in Ethereum, there are tools like ganache to show the entire state of the blockchain, including different log details and the different transaction details. However, in this demo application, we intend to show it by ourselves by leveraging the Hyperledger fabric.

For instance, we have created the ADVIL drug that is added into the blockchain with block number 29. If we click on a particular block number as shown in Figure 8, we will get information like Transaction ID, Block Hash, Channel name, drug name, Time Stamp, etc. This is the powerful feature of blockchain and the Hyperledger fabric. Also, as this data is immutable, no one can change it. Each successful entry will be recorded as a transaction or a block in the blockchain network. In our application, whenever we create a drug, it is considered as a transaction and this particular transaction is added as a block into the

blockchain, which is then distributed among all the peers in the network.

Entity need to approve it for retail in pharmacies. Figure 9 shows the login interface of the DAO.

So, once we approve, say ADVIL medicine, then after a successful operation, the number of blocks is now 30 with the 30th block content containing the key-value pair with the approved message, as shown in Figure 11. That is how the DAO will approve drugs.

We get the drug info from the blockchain. We created a few drugs, and the number of blocks till now is 29. The ADVIL medicine has pending approval as shown in Figure 10.

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Now moving to the government interface. After login, we will see the drugs approved by DAO. Now, the government needs to approve it. After the government approves it, a successful notification will come up and this transaction is then recorded into the

blockchain network. Now, as shown in Figure 12, the drug ADVIL has been approved by the DAO and has approval pending from the Government. So, once the government approves ADVIL, then a successful transaction notification will pop up with the transaction ID, and this successful transaction is added as a block in the blockchain network. Hence, now the total blocks become 31.So, now that the DAO and the government have approved the drug, it is now cleared for retail in pharmacies. So, if we log in to the pharmacy or the hospital interface, this will show all the drugs that are genuine and have been approved by FDA and the government, as summarized in Figure 13.

This analytic section is just provided to show how data comes in near real time through the blockchain and it can be used for different charting and statistical purposes also. So, this is just to show that data appears very fast and can be used by many analytics companies for reporting statistics data for those purposes

Now that drugs are approved, they are available to be purchased at pharmacies. So, now, we log into the customer interface. In this interface, the patient, or the customer can purchase approved drugs that are at the pharmacy, as shown in Figure 15. So, he will enter his details like name, age, email, etc. Then select a condition like fever, influenza, etc.,

and then select the medicines that are available for purchase (the approved drugs) and ready for sale. Once we submit these customer details, it is sent to the doctor or the medical professional who will approach the prescription, and this will be added as a transaction/block in the network. Hence, now the total blocks become 32.

Once we submit these customer details, it is sent to the doctor or the medical professional who will approach the prescription, and this will be added as a transaction/block in the network. Hence, now the total blocks become 32. We can see that the customer details have been passed on to the doctor and has pending approval, shown in Figure 16.

So, now we will finally log in with the doctor's interface, by giving the required certificate. Here, we can see the customer's prescription & the drugs that he requires. So if the doctor feels that the prescription is okay, then he can approve it. The successful approval counts as a transaction and will be recorded as a block in the blockchain network. Now, the block count becomes 33, as shown in Figure 17

Therefore, after that, if the customer logs into the customer's interface, he can see that the required drug is now approved for purchase. Hence, this forms the entire flow of the proposed model. We started from the manufacturer and ended with the customer. With the help of Hyper ledger Fabric, we can remove the counterfeiting drugs from the market because this type of network is totally transparent and tamper-free.

IV.   CONCLUSION

Serious health issues, including deaths, may occur if the users consume counterfeit drugs. Several counterfeit drugs have been detected in the market of lower / middle income countries. Hence, detecting such fake drugs in the market is a big challenge. Keeping their threats in mind, in this paper, we have proposed a blockchain based model to detect such fake drugs. The proposed model also aims to track the movement of drugs from the industry to the patient. We have used the Hyperledger fabric to implement the entire model. In the proposed model, the manufacturer first has to upload the details of a drug which is sent further to the government for approval. Once it is approved, the pharmacies can request the approved drugs within the blockchain network. Further, if a patient needs to get some medicine/drugs, then a corresponding request is made into the blockchain network. Then, a medical officer/doctor approves or rejects his request. Because the entire model is implemented in a blockchain network, it can prevent counterfeiting of drugs and we can easily track the movement of drugs from the manufacturer up to the patient.

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