2021 2nd International Conference for Emerging Technology (INCET)
Belgaum, India. May 21-23, 2021

Counterfeit Medicine Identification Using Hyperledger Based Private Blockchain

1st Saha Reno[1], 2nd Iqramuzzaman Sadi[1], 3rd Jony Karmakar[1], 4th Md. Abir[2]
Dept. of Computer Science and Engineering
Bangladesh Army International University of Science and Technology, Cumilla, Bangladesh[1]
North South University, Dhaka, Bangladesh[2]
reno.saha39@gmail.com, sadivictorian@gmail.com, jonykarmakar1996@gmail.com, abir@northsouth.edu

2021 2nd International Conference for Emerging Technology (INCET) | 978-1-7281-7029-9/20/$31.00 ©2021 IEEE | DOI: 10.1109/INCET51464.2021.9456418

***Abstract*—Nowadays, counterfeit medicine is considered a serious issue, especially in the developing and least developed countries. The lack of transparency and utilization of proper technologies, along with consumers unawareness have made this massive global threat a bit more difficult to handle, which affects the society both economically and physically. Though there are numerous technologies to identify the authenticity of a medicine in modern countries, detecting counterfeited medicine is a tough process from the perspective of the countries struggling to tackle this type of corruption. In this paper, a low-cost private and permissioned blockchain based method is proposed to identify the counterfeit medicine more efficiently and accurately, considering the aspects of countries struggling with this issue. A secure path between medicine manufacturers and consumers is developed to ensure the authenticity of medicines. An emerging technology of Hyperledger security system under the blockchain technology is utilized to develop the proposed approach.**

***Index Terms*—Counterfeit medicine, Hyperledger, Blockchain, Consumer rights, Drugs**

I. Introduction

Drugs are used to cure, prevent or treat diseases, ease pain, eliminate or reduce symptoms and slow down the outspreading of several infectious diseases. Counterfeit is something made for a dishonest purpose; something that is not real but presented as or appears to be real [1]. World Health Organization (WHO) characterizes spurious drugs as one which is purposely and falsely mislabeled, causing several health issues for the consumers. In case of developing and underdeveloped countries , a large number of dishonest and unauthorized companies are exploiting the medicine market, selling their counterfeit drugs in parallel with the genuine ones [1], [2]. Treatment with incapable fake drugs can lead to fatal and harmful impacts on a wide area of the populace, resulting in several health issues and detrimental side effects [3]. As a result of such harming effects, counterfeit medicine is imposing a serious threat to the healthcare systems, healthcare experts, providers and vendors of veritable drugs, the pharmaceutical industry and medical administrative authorities [4].

Most of the people of these countries are considered to be incapable of distinguishing real medicines from the fake ones. A preventive solution of this issue can be buying medicines from the outlets of manufacturing companies which can ensure consumers getting authentic medicines [5]. However, no significant or a few number of legitimate outlets can be found. A few outlets exist but no access is provided to the retailers or customers rather than the wholesalers. Additionally, counterfeit medicine does not only bring several health issues but also adversely affects the medicine manufacturers and consumers economically. The pharmaceuticals companies are losing their revenues every year for trading of these unauthentic medicines in the market.

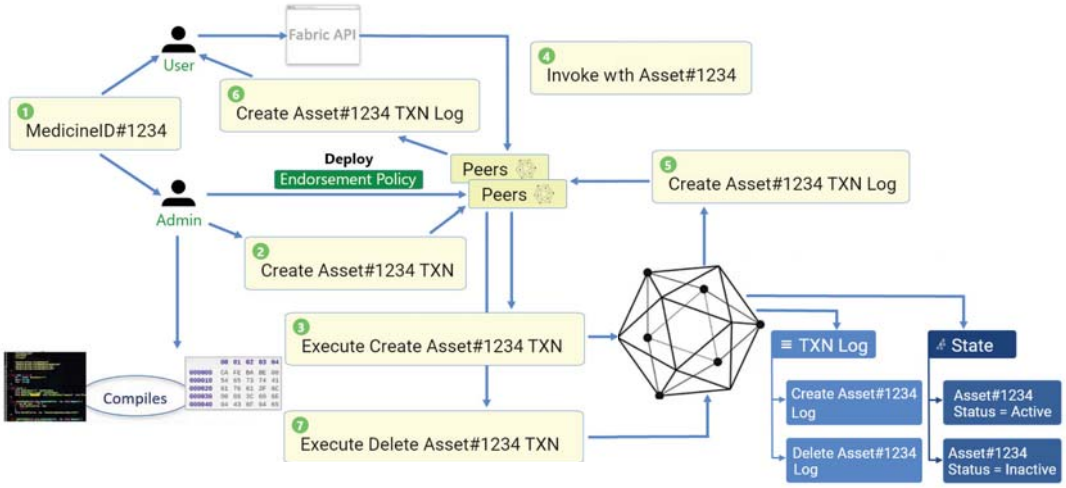
Numerous challenges exist to ensure a highly sophisticated secure system to identify fraud medicines. A reliable communication path between legitimate manufacturers and consumers can be established by building up systems which utilize secure encryption mechanisms and network security techniques [5]. Systems implementing Data Encryption Standard (DES) and Advanced Encryption Standard (AES) are eligible to block various types of intrusions effectively. However, modern adversaries and intruders are sufficiently smart to break through any secure system to steal and modify confidential information. Several cyberattacks exist in the literature which can make any system insecure, vulnerable and ineffective.

Different approaches were proposed to tackle this issue. Researchers have employed promising technologies like Radio Frequency Identification (RFID) tags [6] and public blockchain platforms like GCoin [9], which are considered infeasible as space and time complexity is large for the aforementioned solutions. Amplifying supply chain using public blockchain [13] was also proposed, but in this case the system becomes hard to operate and complex exploration technique makes the system almost unusable.

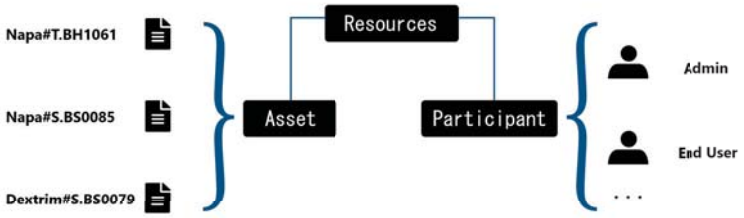
In this work, we propose a more secure and reliable fraud identification platform embedded with Hyperledger based private blockchain. Blockchain technology is one of the most secured means of protecting sensitive and valuable information as it offers optimum confidentiality and immutability. Our proposed system blocks every unauthorized access to execute and retrieve transaction history from the historian registry. Moreover, our system easily overcomes the drawback of server based classical information storage system, from which the confidential information can be accessed and modified using different types of cyber-attacks.

The rest of this paper is organized as follows. Section II introduces the highlights of our proposed approach. Section III presents an overview of previously conducted researches intended to tackle the trading of fake drugs and other commercial sectors, along with their weakness. Section IV describes

978-1-7281-7029-9/21/$31.00 ©2021 IEEE



(a)



(b)

Figure 1: System Architecture of Our Proposed Hyperledger Based Counterfeit Medicine Detection: (a) System's Information Flow and Interaction with Blockchain, (b) System Resources

our proposed framework. Section V then discusses the experimental results of our detection technique. Finally, Section VI concludes this paper with a summary of the key contributions and results.

II. Proposed Approach

In this paper, a framework for counterfeit medicine detection by the end user is proposed utilizing Hyperledger Fabric technology. Hyperledger Fabric is a private blockchain where the confidential information of a company are kept private and immutable in nature. Medicine users can justify the authenticity using those confidential information. Transactions executed from admin and user ends remain unchangeable in the system, so that the robustness of traceability is strengthened.

In the proposed system, a medicine company creates a medicine ID for each of the medicine they produce. This ID is generated when a new asset is created inside the private blockchain system through an immutable transaction. The manufacturer labels the packet of the medicine using those identifiers, coated by an opaque substance. Users need to scratch off the coated medicine ID and input it in the system's web portal. Particular transaction executed for the creation of specific medicine information is then fetched from the blockchain and forwarded to the user. At the same time, peers of the hyperledger fabric executes the asset deletion transaction to remove the medicine information already fetched by the buyer and stores the user ID along with other necessary information e.g. timestamp inside this transaction (to identify who has previously verified the medicine if the medicine ID is reused for verification). If the fake medicine manufacturers reuse genuine medicine IDs in their package, buyers of counterfeit medicine will not find any medicine information for a reused medicine ID as the asset is deleted from the system and the information of the transaction responsible for the deletion will be forwarded to the buyer which includes the previous verifier and the verification time. The main strength of our system lies in the unchangeable nature of the information stored inside the blockchain, where the server and database

based verification is vulnerable to various cyber-attacks which can alter the original information. The system architecture of our proposed system is illustrated using Fig. 1.

III. Related Works

A group of researchers in their paper [6] identified a solution of detecting counterfeit medicines using Radio Frequency Identification (RFID) with transceiver activating multiple antennas. RFID tags can hold a large amount of data in its storage. The drawback of this solution is the price of RFID tag which is much higher and thus increases the price of medicine stripe. A practical demonstration of blockchain technology was first presented in foreign trade management [7]. Blockchain can secure the tracking system while importing and exporting products, but the quality of imported or exported products can't be justified using this technology.

Another group of researchers in their paper [8] presented the immense adaptability of blockchain in business sectors incorporating its capabilities into their operations. Due to the large complexity and public nature of of classical blockchain infrastructures: (a) operating blockchain based systems become difficult, (b) the privacy is not maintained, (iii) information transferring among the departments is costly as cryptocurrencies are required. Authors in [9] show a new application named Gcoin by Blockchain to create transparent drug related transactions. With Gcoin blockchain, the governance model of the drug supply chain could shift from regulating (only by government audits) to surveillance net (by every participant who involves the supply chain). A blockchain pharmacosurveillance framework is established in Philippine that enables the exchange of knowledge within the official distribution network of drugs [10]. The drawback of this framework is that it is highly time consuming in case of exchanging information. A work in [11] presented which does not only detect counterfeit medicines but also faciliateds the detection of poor-quality drugs. However, without a differentiated analysis considering: (a) therapeutic class, (b) source and (c) country of counterfeit drugs, the difficulty to identify the root causes of market infiltration still remains and thus useful points of attack to combat them cannot be identified. In the same way, authors in [12] provide a solution to identify fraud medicine supply chain utilizing blockchain and scrambled QR (quick reaction) code security. The imperfection of this system lies in the requirement of cryptocurriencies for executing transaction, which is not available to most of the general medicine users.

In [13], researchers displayed a blockchain based course of actions to amplify supply chain security for the pharmaceutical industry. The deployment of blockchain based supply chain security system requires understanding the complicated terminologies of blockchain and most of them have insufficient knowledge about this emerging technology. An orderly survey of the continuous investigation within the application of blockchain innovation in healthcare is presented in [14]. The inquiry of this system utilized four logical databases which ultimately makes the system vulnerable to several database attacks.

Transaction Executing Utility for MedicineInfo Asset Creation, Deletion and Emitting Event

```
Execution of Transaction for Creating Report:
    Input: ID no. of the MeidicineInfo Asset, Name of Medicine, Amount of Mixture in mg,
Amount of Liquid in ml, Type of Medicine, MFG Date, EXP Date


    medicineInfoRegistry ← Instance of
getAssetRegistry(org.counterfeit.medicineInfo.MedicineInfo)
    factory ← Instance of getFactory()
    NS ← org.counterfeit.medicineInfo


    medicineInfo ← Instance of factory.newResource(NS, 'MedicineInfo', medicineData.IDNo)
    det ← New Details Concept Creation Using factory.newConcept (NS, "Details")


    det[3] ← [medicineData.medicineAmountInMG, medicineData.liquidAmountInML,
medicineData.medicineType]
    report.amountAndType ← det

    medicineInfo.medicineName ← medicineData.medicineName
    medicineInfo.MFGdate ← medicineData.MFGdate
    medicineInfo.EXPdate ← medicineData.EXPdate


    event ← Instance of factory.newEvent(NS, "MedicineInfoCreated")
    event.IDNo ← IDNo
    emit(event)

    return medicineInfoRegistry.add(medicineInfo)


Execution of Transaction for Removing MedicineInfo:
    Input: ID no. of the MeidicineInfo Asset

    medicineInfoRegistry ← Instance of
getAssetRegistry(org.counterfeit.medicineInfo.MedicineInfo)
    NS ← org.counterfeit.medicineInfo

    event ← Instance of factory.newEvent(NS, "MedicineInfoDeleted")
    event.IDNo ← IDNo
    emit(event)

    return medicineInfoRegistry.remove(medicineData.IDNo)
```

Figure 2: Utilization Technique of Executing Create-Delete Transactions

Another group of researchers focused on blockchain technology to minimize this massive global problem. Transactions related to the production of drugs are stored in the private blockchain ledger. Besides blockchain, Various new technologies were also utilized in their work [15], [16], but the cryptocurrency requirement issues are clinged to these ideas. Few more steps were also taken by some other researchers to overcome the problem of counterfeit medicines though there are not much details available about the system's effectiveness measurement using sufficient analysis and how efficiently the problems regarding the counterfeit medicine can be handled in [17], [18].

The above drawbacks are eliminated by applying Hyperledger based permissioned blockchain in case of counterfeit medicine detection, which does not require cryptocurrencies for the transactions to be executed, has query feature like classical database approach and offers faster transaction processing time.

IV. Proposed Detection Method

As the private blockchain of our system is based on Hyperledger Fabric, the assets and transactions in charge of creating, altering or omitting these assets are two major counterparts of our proposed framework. In our system, the asset ID and transaction ID are utilized to detect whether a medicine is

counterfeit or genuine. The systematic procedure of identifying counterfeit medicine is described in the following sub-sections:

A. Defining The Assets

Information about a certain medicine is denoted as a particular asset of our system which includes the medicine ID, medicine name, manufacturing date and other related information. These information are collectively referred to asset definition. Each of these assets are generated and stored inside the asset registry of our private blockchain. These assets of our systems are identified by the medicine ID and indexed in the asset registry by this identification number. Information about a specific asset can only be created and modified via transactions to ensure the immutability of the history about these assets. Asset ID is labelled in the packaging of the medicine and coated with an opaque substance which can be scracthed off by the user to reveal the medicine ID. This medicine ID is then used by the blockchain based web application to detect whether this medicine information is available in any of the blocks of our private blockchain.

B. Execution of Transactions

Like any other blockchain systems, every possible operations of our proposed blockchain based protocol is executed using transactions. Once a transaction is stored in any of the blocks inside the chain, it becomes immutable, meaning that without any major attack like 51% attack, which is practically infeasible to execute, these transactions can not be altered. Our system has two major transactions among others, which are used to prevent the trading of fake medicines in the market: (i) Create Asset and (ii) Delete Asset. The definition of asset creation transaction comprises of the same parameters included in the asset definition. On the other hand, the transaction responsible for deleting an asset only requires the asset ID to be deleted. When a transaction for creating or deleting an asset is executed, a particular transaction ID is generated and the transaction is easily traced from our private blockchain by this transaction ID. The implementation of utility function for both creating and deleting asset transactions is illustrated in Fig. 2.

C. Determining Participant Types

According to the Hyperledger Fabric, every private blockchain requires participants, so as our system. In our proposed architecture, two types of participants are required to operate the system: (i) System Admin and (ii) End Users. All the responsibilities of the participants are discussed in the following sub-sections.

1) System Admin: Admin of the system is allowed to create assets and fetch the historian record (which is described in the succeding sub-section) and asset registry. Although the default permission range of the end users of our system is limited to only searching and fetching particular asset information and instantaneously delete the fetched asset, the dominion can be ascended or descended by the system admin. Moreover, the system admin is authorized to generate extra participants

Validating Medicine Genuineness by Accessing Transaction and Asset Registries

```
Query AccessHistorianRecord:
    description ← "Returns Historian Records"
    statement ← SELECT org.hyperledger.composer.system.HistorianRecord where
(transactionType == _$input)

Query AccessAssetRegistry:
    description ← "Returns Asset Registry Elements"
    statement ← SELECT org.hyperledger.composer.system.AssetRegistry where (assetID
== _$input)

accessSpecificAsset:
    bnUtil ← Business Network Definition of Counterfeit Medicine Prevention System
    assReg ← bnUtil.connection.query('AccessAssetRegistry')
    qry ← bnUtil.connection.buildQuery(assReg)
    return bnUtil.connection.query(qry,{input: assReg#ID)

accessDeleteAssetTransaction:
    bnUtil ← Business Network Definition of Counterfeit Medicine Prevention System
    histRecs ← bnUtil.connection.query('AccessHistorianRecord')
    qry ← bnUtil.connection.buildQuery(histRecs)
    return bnUtil.connection.query(qry,{input: 'deleteMedicineInfo')

checkAssetValidity:
    Input: Asset/Medicine ID

    asset ← accessSpecificAsset(assReg#ID)
    if asset IS void
        then historianRecs ← accessDeleteAssetTransaction()
             for record in historianRecs:
                    if record.MedicineID IS assReg#ID
                        return record

    else
         historianRecs ← accessCreateAssetTransaction()
         for record in historianRecs:
                    if record.MedicineID IS assReg#ID
                        execute DeleteMedicineInfo(assReg#ID)
                        return record
```

Figure 3: Querying Methods to Access and Search Asset Registry and Historian Record

types (if required) for better manageability of the system in the future upgradation. The smart contract and accessibility of our Hyperledger based blockchain are also managed by the admin.

2) End Users: After a user becomes the active participant of our system, he/she can fetch the asset information by providing the particular medicine ID. After extracting an asset information from the asset registry, the transaction to remove that specific medicine information is executed from the user end and the user ID is stored inside the transaction. The permission of altering the chaincode, creating a new asset, updating the asset information are not assigned to end users. The subscription of the active users can be cancelled by the system admin if any violation of rules is incurred.

D. Storing Assets Inside Asset Registry

All the asset information are stored inside the system's asset registry. If the system admin or an end user wants to retrieve the details of any specific asset, it is required to provide the asset ID inside this registry. By utilizing the querying method of our system, this registry can be searched for specific medicine information. If any asset is removed from the registry, our system does not actually delete the asset information to preserve the immutable characteristic of blockchain. Instead, the status of that particular asset is changed from 'Active' to 'Deleted'. The status 'Deleted' indicates an already purchased medicine and thus restrain the fake medicine producing organization from reusing the same medicine ID at the time of packing the counterfeit medicine. If the status is 'Deleted', the asset registry indicates the non

Table I: Random Medicine Information for System Evaluation Purpose
Source: Beximco Pharmaceuticals Ltd, Bangladesh

Serial No.	Medicine Name	Type	Medicine ID	Manufacture Date	Expiry Date
01	Napa	500mg (Tablet)	T. BH1061	APR 20	OCT 20
02	Napa	125 mg/5ml (Syrup)	S. BS0085	APR 20	OCT 20
03	Dextrim	(20 mg+10 mg+2.5 mg)/5 ml (Syrup)	S. BS0079	JUN 20	MAY 21
04	Axodin	120 mg (Tablet)	T. BH0015	SEP 20	AUG 21
05	Kovicin	200 mg (Tablet)	T. BH0201	DEC 20	NOV 21
06	Ecotrim	10 g (Cream/ Ointment)	C. BC0043	JAN 20	JAN 21
07	Dexoride	100 ml (Fluid)	F. BF2056	MAR 20	DEC 20
08	Clinacyn	300 mg (Capsule)	CS. BH1526	OCT 20	OCT 21

existence of that specific medicine, though the asset still exists in the registry.

E. Placement of Transactions Inside Historian Record

All the transactions executed inside our private blockchain are stored inside the blocks and can be retrieved from historian record. Along with the transaction ID, historian record is also indexed by the ID of the chain user who has executed the transaction and also by the type of the transaction. Our system includes different types of transactions but to prevent the trading of counterfeit medicine, two types of transaction are mainly required: (i) CreateMedicineInfo, (ii) DeleteMedicineInfo. Hyperledger Fabric supports queries like traditional databases. By exploiting this feature inside the asset registry and historian record, it can be acknowledged whether a particular medicine exists or already been verified by a system user. Utilization technique to detect couterfeit medicine using query language, asset registry and historian record is discussed in subsequent section.

F. Validation of Genuineness

In our system, queries are defined for: (i) Exploring asset registry for a particular asset using asset ID, (ii) Finding a specific transaction from historian record using the type of transaction. After the user provides a medicine ID labelled on the packet to our system, blockchain peers execute the first query to check whether the asset exists or not. If the asset exists, it is considered that the asset has not been previously verified for genuineness validation. Then the peer of our system executes the second query using the type: CreateMedicineInfo#MedicineID, fetches the transaction data and forward it to the user. After this, the peer executes DeleteMedicineInfo#MedicineID transaction to remove that particular asset from our hyperledger and the ID of the user who has verified the medicine is attached with the transaction in historian record. In the second case, if an already verified medicine is searched for the second time, the result of the first query will be void and the peer executes the second query with the type DeleteMedicineInfo#MedicineID. All the returned transactions from that query are explored for the particular medicine being searched. This particular transaction is forwarded to the user, which includes the user ID who has already verified the medicine, the timestamp of the verification, the transaction ID etc. The later incident indicates the second time verification or the fraud medicine trader used the asset ID

Participant Creation, Assigning Identities and Providing Participants The Access to Execute Transactions

Assigning Identities to End-Use Participant:

```
    participantInstance ← composer.participant.add(class: EndUser, participantKey:1234, fname:
Saha, lname: Reno, contactNum: 01521234214, email: saha.reno@baiust.edu.bd)

    composer.identity.issue(participantInstance, admin@counterfeit-medicine-prevention)
```

Defining Access Control for System Admin and End Users:

```
Rule AdminSystemResource:
        description ← "Grant business network administrators full access to system resources"
        participant ← "org.hyperledger.composer.system.NetworkAdmin"
        operation ← ALL
        resource ← "org.hyperledger.composer.system.**"
        action ← ALLOW

Rule EndUserPermissionHistorianRecordREAD_CREATE:
        description ← "Can VIEW and CREATE HistorianRecord inside the Historian"
        participant ← "org.counterfeit.participants.EndUser"
        operation ← READ, CREATE
        resource ← "org.hyperledger.composer.system.HistorianRecord"
        action ← ALLOW

Rule EndUserPermissionHAssetRegistryREAD:
        description ← "Can only VIEW Assets inside the AssetRegistry"
        participant ← "org.counterfeit.participants.EndUser"
        operation ← READ
        resource ← "org.hyperledger.composer.system.AssetRegistry"
        action ← ALLOW

Rule EndUserPermissionRemoveMedicineInfoCREATE:
        description ← "Can EXECUTE RemoveMedicineInfo transaction"
        participant ← "org.counterfeit.participants.EndUser"
        operation ← CREATE
        resource ← "org.counterfeit.medicineInfo.RemoveMedicineInfo"
        action ← ALLOW

Rule EndUserPermissionMedicineInfoREAD_DELETE:
        description ← "Can VIEW and REMOVE MedicineInfo Assets"
        participant ← "org.counterfeit.participants.EndUser"
        operation ← READ, DELETE
        resource ← "org.counterfeit.medicineInfo.MedicineInfo"
        action ← ALLOW
```

Figure 4: Access Control Setup for Limiting Blockchain Access

of any genuine medicine in their packaging. Implementation technique of accessing asset registry, historian record and validating genuineness is depicted in Fig. 3.

G. Setting Up The Permission Regulations

In our system, the access to the system resources like the business definition, transaction registry, asset registry and transaction can be restricted to particular users using the Access Control feature of Hyperledger Fabric. System admin is privileged to access most of the system resources but only with an exception. The permission to execute the transaction to delete a medicine information is not given to the admin but the end users have the access to execute that transaction. End user also have the permission to fetch data from both the asset registry and historian record. No access to the transaction responsible for creating assets is given to the end users to restrict fake end users of fraud medicine organizations, so that they are unable to store any fake medicine information

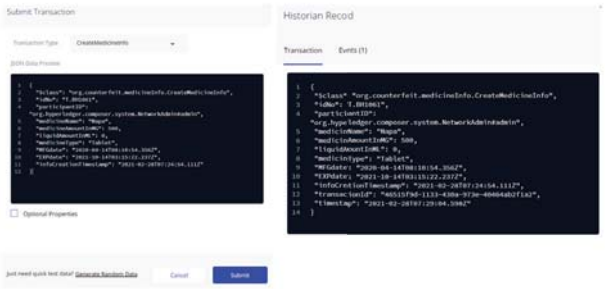


Figure 5: Execution of CreateAsset Transaction and Accessing from Historian Record

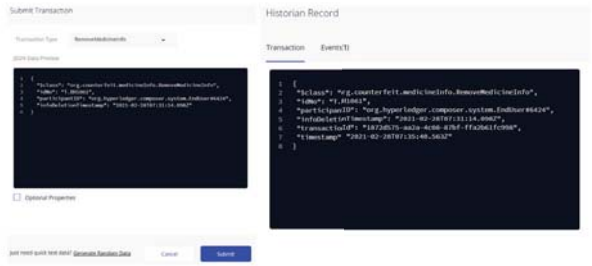


Figure 6: Execution of DeleteAsset Transaction and Accessing from Historian Record

in the blockchain. The utilization of Access Control feature of Hyperledger Fabric in our system is illustrated in Fig. 4.

V. Result Analysis

We have collected and used some of the medicine information from Beximco Pharmaceuticals Ltd, one of the leading pharmaceutical companies of Bangladesh. to evaluate our system. A sample of the medicine information is shown using Table 1.

Using the admin privilege, the information about the first medicine of the Table 1 is created using the asset creation transaction and then stored inside the blockchain. Execution of

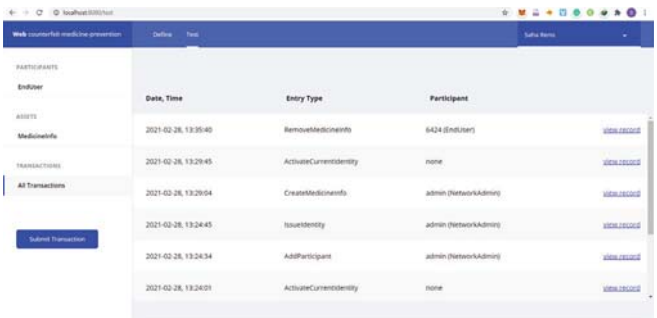


Figure 7: Indexed Historian Record

Table II: Required Amount of Time for Executing Transactions in Several Blockchain Technologies

Number of Transactions	Time for Bitcoin	Time for Ethereum	Time for Hypeledger
100 Txn	14.29 seconds	11.11 seconds	0.33 seconds
80 Txn	11.43 seconds	8.88 seconds	0.27 seconds
60 Txn	8.57 seconds	6.66 seconds	0.20 seconds
40 Txn	5.71 seconds	4.44 seconds	0.13 seconds
20 Txn	2.85 seconds	2.22 seconds	0.0667 seconds

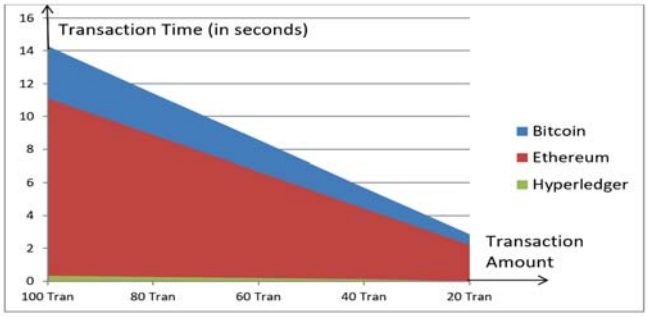


Figure 8: Time Complexity Comparison for Three Blockchain Systems

AssetCreation transaction and accessing the transaction using asset ID is depicted using Fig. 5.

After accessing the transaction information about first medicine, the peer of our blockchain system peer execute the asset deletion transaction and this transaction data is forwarded to the user who verifies that particular medicine for the second time. Executing the deletion transaction and fetching the transaction information is depicted in Fig. 6.

The historian record list for accessing particular assets and transaction records can be obtained from our system and is shown in Fig. 7.

To evaluate the efficiency of Hyperledger based medicine counterfeit system, we have generated some random medicine data and measured the required time to insert those information in Bitcoin based blockchain and Ethereum framework. Table 2 along with the graph in Fig. 8 depicts that hyperledger aids the detection of counterfeit medicine by faster information storing time.

VI. Conclusion

The permissioned and private nature of Hyperledger Blockchain has made the verifcation of the genuineness of medicine much more secure and reliable than other public and permission-less blockchain based platforms. As Ethereum requires cryptocurrency for executing any type of transaction and transaction data is publicly available, it is indeed not suitable for developing a counterfeit medicine identification system. The Hyperledger based permitted network utilizes the historian record of the decentralized network, in which a recorded transaction can not be altered by any means. Moreover, restrictions are applied to the participants based on their roles in the system, which is not possible in any permission-less Blockchain system.

REFERENCES

[1] O. V. Buowari, "Fake and counterfeit drug: a review," *Afrimedic Journal*, vol. 3. Issue 2, pp. 1–4, July, 2012

[2] FDA, "Counterfeit Medicine," *U.S. Food & Drug, New Hampshire Ave*, August, 2019.

[3] D. Ziance, J. Ronald, "Roles for pharmacy in combatting counterfeit drugs," *Journal of the American Pharmacists Association*, vol. 48. Issue 4, pp. 71–91, June, 2008.

[4] A. Blackstone, A. Erwin, P. Joseph and S. Pociask, "The health and economic effects of counterfeit drugs," *American health & drug benefits*, vol. 7. Issue 4, pp. 216, June, 2014.

[5] IRACM, Prevention. Accessed at www.iracm.com/en/ commitment-and-strategy/prevention/

[6] M. Hamid, M. Zeeshan and A. Ramish, "Counterfeit drugs prevention in pharmaceutical industry with RFID: a framework based on literature review," *International Journal of Architectural and Environmental Engineering*, vol. 8. Issue 4, pp. 203–211, 2014.

[7] S. Toapanta et al, "A Hyperledger Technology Approach to Mitigate the Risks of the Database in Foreign Trade Management," *3rd IEEE International Conference on Information and Computer Technologies (ICICT), San Jose, CA, USA*, May 2020.

[8] M. Mettler, "Blockchain technology in healthcare: The revolution starts here," *2016 IEEE 18th international conference on e-health networking, applications and services (Healthcom), Munich, Germany*, pp. 1-3, , 2016.

[9] J. Tseng, Y. C. Liao, B. Chong and S. W. Liao, "Governance on the drug supply chain via gcoin blockchain," *International journal of environmental research and public health*, vol. 15, pp. 1055, 2018.

[10] Sylim, Patrick, Fang Liu, Alvin Marcelo, and Paul Fontelo. "Blockchain technology for detecting falsified and substandard drugs in distribution: pharmaceutical supply chain intervention," *JMIR research protocols*, vol. 7, no. 9 (2018): e10163.

[11] K. Andreas and J. Dressman, "Poor-quality and counterfeit drugs: a systematic assessment of prevalence and risks based on data published from 2007 to 2016," *Journal of Pharmaceutical Sciences*, vol. 106, no. 10, pp. 2921–2929, 2017.

[12] K. Randhir and R. Tripathi, "Traceability of counterfeit medicine supply chain through Blockchain," *11th International Conference on Communication Systems & Networks (COMSNETS), Bengaluru, India*, pp. 568–570, 2019.

[13] S. M. Manuela et al, "Blockchain technology in the pharmaceutical industry," *Frankfurt School Blockchain Center: Frankfurt, Germany*, 2017.

[14] A. C. Cornelius, Q. H. Mahmoud and J. M. Eklund, "Blockchain technology in healthcare: a systematic review," *Healthcare, Multidisciplinary Digital Publishing Institute*, Vol. 7, No. 2, 2019.

[15] H. Ijazul and O. M. Esuka, "Blockchain technology in pharmaceutical industry to prevent counterfeit drugs," *International Journal of Computer Applications*, vol. 180. Issue 25, pp. 8–12, March, 2018.

[16] S. Khanna, N. Atul and G. Arun, "Counterfeit drugs: problems and solutions," *International Research Journal of Pharmacy (IRJP)*, vol 1. Issue 1 pp. 1–6, December, 2010.

[17] U. Sarah, "Blockchain beyond bitcoin," *Communications of the ACM*, Issue 2, pp. 15–17, June 2016.

[18] P. Gupta, K. Singhal and A. Pandey, "Counterfeit (fake) drugs & new technologies to identify it in India," *International Journal of Pharmaceutical Sciences and Research*, vol 3. Issue 11, pp. 4057. July, 2012.