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Blockchain, Snap Tags, and QR Codes for Combating the Subtle Crime of Drug Counterfeiting

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ABSTRACT
One of the most serious crime or offenses against public health is the manufacture, distribution, and sale of fake medications and other medical supplies. The act of "deliberately and fraudulently mislabeling pharmaceuticals with respect to their identity or source" is known as drug counterfeiting. Both branded and generic products can be counterfeited, including those that have incorrect components, insufficient active substances, or none at all. Legitimate medications that have reached their expiration date may be included. In certain cases, low quality is noted along with a bogus expiration date. Treatment failure, end organ damage, toxicity, loss of confidence, illness escalation, and occasionally significant financial loss are all consequences and dangers of using counterfeit pharmaceuticals. The majority of current solutions either rely heavily on computational resources or are purely theoretical research. The deadly threat of drug counterfeiting needs to be reduced, and there is a need for a more secure, scalable, but simple to implement solution. Therefore, this study describes the creation of a system for detecting fake drugs that combines blockchain technology with QR codes and SnapTags. The proposed system performs admirably in comparison to some of the current related systems, even surpassing some of them.

General Terms
Pharmacy, Drugs, Health, Blockchain, Cybercrime.

Keywords
Drugs, Blockchain, Cloud Computing, Information Security, Agro-extension.

1. INTRODUCTION
At every level of healthcare, medications are essential. They are helpful for maintaining health, diagnosing, preventing, curing, treating, or attenuating illnesses or disorders, and preventing disease or symptom onset [1]. Drugs can provide an easy, affordable solution to many health issues if they are readily available, reasonably priced, of high quality, used properly (as directed by a doctor), and not obtained through unethical ways [2]. Drug expenses make up a significant portion of the overall health budget in many nations. Despite the clear medicinal and economic significance of medications, the issue of counterfeiting is still a major one [3].

The fabrication of medicines and pills through fraud and adulteration is a long-standing practice that thrives in many nations. It is primarily driven by the enormous profits that may be generated, which have been greatly increased by contemporary manufacturing and trade [4].

Both developed and developing nations appear to be impacted by the international trade in fake medications. The spread of fake medications is typically more pronounced in nations with less stringent regulations on the production, importation, distribution, supply chain management, and sale of pharmaceuticals. These nations may require significant enforcement efforts to strengthen regulatory agency monitoring systems. The term "counterfeit," which was once widely used to designate any drug that is not what it purports to be, is currently under debate. A medicine that violates a registered trademark is considered a counterfeit drug in the strictest legal sense. Any medicine created with deliberate deception is included in the lay definition, which is far broader. Some generic pharmaceutical businesses and civil society organizations disagree with the term "counterfeit," perceiving it as a purposeful combination of intellectual property and public health issues [5-6].

One of the most serious offenses against public health is the manufacture, distribution, and sale of fake medications and other medical supplies. Like any other form of economic fraud, this crime hurts legitimate producers, distributors, and pharmacies since they lose money, damage the reputation of the pharmaceutical company, and occasionally even have to compete with distributors of fake goods [7].

The harm done to people's lives and health, which cannot be overstated, has the worst effects. Such harm can range from causing death or major health injury due to the use of low-quality medications and/or the absence of adequate therapeutic impact, misleading diagnostic results, etc. to creating mistrust in doctors as a result of unsuccessful treatment. While it can be challenging to prove these consequences exist and that using fake medications has harmed people's lives or health, doing so is far more challenging [5][8].

A drug that has been purposefully and fraudulently mislabeled with regard to its source is considered to be counterfeit [5]. Both branded and generic products that include incorrect components, insufficient active substances, or goods without any active ingredients are considered counterfeit. The list of counterfeit pharmaceuticals includes those that contain fewer or no active ingredients than those listed, as well as those that have been adulterated, substituted, completely misrepresented, or sold under a false brand name. In some cases, genuine pharmaceuticals that have expired may be marked with a false expiration date to indicate low quality. A fake drug or pharmaceutical product is one that is created or distributed with the intention of misrepresenting its source, validity, or efficacy. A fake medication could have insufficient amounts of the active chemicals or none at all. It might also be inadequately absorbed

by the body or have ingredients that are not listed on the label. A number of technologies might be useful in the fight against the problem of fake drugs.

False drugs, also known as counterfeit drugs, are unsafe for use and human consumption and pose a risk to health. Not just in underdeveloped nations, where it can make up to 45% of the market, drug counterfeiting is becoming an increasingly serious threat. Some counterfeiting is challenging to identify, look into, measure, or put an end to. It is challenging to estimate how much medication is being sold illegally. Though it happens everywhere, counterfeiting is most prevalent in Nigeria, Africa, and India. A fake pharmaceutical could have the same packaging as the real thing. These fake medications are frequently so well disguised that even a forensic expert cannot physically identify the difference [5][8].

The sale of fake drugs is a lucrative crime that spreads more and more each year. The issue of counterfeit medications is widespread worldwide, has increased significance in light of rising globalization, and is becoming dangerous in the majority of nations. False firms are created, fraudulent certificates and paperwork are obtained, and counterfeiters use a variety of methods to export and import machinery and medicinal materials. Drugs that are counterfeit are illegal, unhealthy, and advance disease. They are also widespread during epidemics and disease outbreaks, when it is most likely that there will be a lack of necessary medications and that counterfeiting will increase. A fake version of the malaria medicine chloroquine made headlines during the COVID 19 (Coronavirus) outbreaks as a potential cure for the virus. It was discovered in Lagos, Cameroon, and other regions of Africa. Many people experienced treatment failure and death as a result of the use of tampered 250 mg chloroquine phosphate tablets, particularly in Lagos, Nigeria. At the LA airport, fraudulent COVID 19 testing kits were also discovered during that time (Los Angeles International Airport).

However, the trafficking in illegal narcotics is a concern that has an impact on public health. In order to better clearly address this issue, this article divides low-quality medications into two primary groups. The first category is comprised of pharmaceuticals that do not adhere to the standards outlined in the manufacturer's dossier or the recognized pharmacopeia. Falsified pharmaceuticals, or those that convey a false representation of identity or source or both, are the other major category of illegal goods. The project will continue to explain many counterfeit medicine types and give permanent drug mitigation through the incorporation of blockchain technology and QR codes or SnapTags as scannable technologies. Unregistered medications, or those without local market authorization, are an issue in many nations. Drugs that are not registered may be of high quality, despite some data suggesting they are frequently not. Unregistered medications frequently circulate outside of the chain of distribution that is supervised; therefore, they are suspicious [5][8].

The most frequently counterfeited medications in developing nations have been those used to treat fatal diseases like cancer, malaria, tuberculosis, and HIV/AIDS. More and more medications are being faked as the problem grows, including pricey ones like anticancer medications and those that are in great demand, like antivirals [9].

According to earlier statements in this project book, there are two main forms of public health drug failures that result in the progression of illness or deaths: faked and substandard. Admittedly, the line separating the two groups isn't always obvious. Drugs that have been falsified are typically also substandard; the national requirements used to define a substandard medicine can change. However, these phrases sufficiently cover the two main areas of concern. The international recognition of these two categories might progress the discussion of the issue [10].

The consequences and danger of counterfeiting drugs includes; treatment failure, end organ damage, toxicity, economic loss, loss of confidence, and even sickness progression. Indeed, the menace of counterfeiting cuts across so many domains. Typical products being counterfeited do not only include drugs or eatable foods; consumer electronics/other electrical components, drinks, tobacco, agricultural products, toiletry products, or even oil and gas products. Although several literature and scientific publication have contributed to efforts directed at mitigating this menace, most of them are mere theoretical analysis. The consequences of counterfeit drugs are enormously dangerous, there is therefore a serious need for a highly secure and efficient system for detecting, reducing or possibly eradicating this subtle killer (Counterfeiting drugs). This paper therefore proposes a blockchain approach for combating counterfeiting especially in drugs.

Utilizing blockchain technology for counterfeit drug detection has many benefits. Such a system will replace the outmoded pharmaceutical supply chain that cannot survive the cyber-security risks of the twenty-first century and lacks visibility, control, and regulation of the manufacture of pharmaceutical products. Additionally, this implementation will do away with centralized server client technical solutions, which have not met expectations due to poor data security, privacy, and authenticity performance. As prescription pharmaceuticals are distributed along the supply chain, the proposed system will act as an electronic and interoperable system to authenticate, identify, and track them. The technology will be able to monitor or trace the flow of medication transactions through various parties involved in the supply chain for pharmaceuticals.

Pharmaceutical companies will have complete control and thus be able to add authorized participants to the blockchain that the company discovers, produces, and receives NAFDAC approval, add unique hash codes (Hash functions), and add all necessary information into the secure distributed ledger before pushing it out to distributors. The distributor will confirm the source of the drugs and upload the transaction to the blockchain; the same is true for wholesalers, pharmacies, and hospitals.

By utilizing Snap Tag or QR Code technology, the suggested system will give the public access to defective, fabricated, and subpar medications. Blockchain technology will be used to detect counterfeit pharmaceuticals and offer updates for the drugs (drugs information). If Snap Tag is eventually implemented, accessibility is universal and not restricted to smartphone/Android phone owners alone. Small cell phones that include cameras can be used for texting.

To put it simply, the key to avoiding all the issues highlighted previously is to establish a coordinated approach to counterfeiting issues. The only way to execute counterfeit drug

detection using blockchain technology is to adopt it and all of its characteristics.

2. REVIEW OF RELATED WORKS

Although the development of cryptocurrencies and other forms of finance initially made blockchain technology prominent. Numerous blockchain use cases have been proposed in a variety of industries, and with the addition of smart contracts, blockchain gained in strength. Since it was initially made public through the usage of bitcoin, expanding its applications to non-financial use cases is a mission that researchers are drawn to. Numerous concepts have been put out to include Blockchain's properties (transparency, distributed ledger technology, security, and traceability), which are immutable and irreversible as well as transparent and secure. The following list includes some scientific articles on this work.

Working on the detection of fake drugs via blockchain was the study in [11], which was basically an effort to update the antiquated pharmaceutical supply chain management system. Additionally, the availability of fake medicines is growing yearly. In order to track the distribution of medications from producers to patients and reduce the likelihood that they would be falsified, the research suggested using a blockchain model. The Authors employed the peer-to-peer Hyperledger Fabric network in a browser (Manufacturer to Government to regulative body to consumer and so on). Users are shown the application's front end so they can initiate transactions using their credentials and send requests to all of their peers through a webpage. Endorser executes a legitimate transaction, and committers check the outcome before writing it to the ledger. A major shortcoming of the work was the disregard for the need for customers to be able to verify authenticity of drugs right from any pharmacy and report any anomaly directly to Manufacturer. Apart from Manufacturer, other participant on the network e.g., Hospital, Pharmacy, Distributor, Wholesaler should be able to see approved drugs or available drugs on the blockchain network, using their digital signature since, the system is distributed.

The article in [12] reported a study on counterfeit drug detection using blockchain. The researcher combined a metal mask with the Ethereum blockchain network via Chrome installation. Every node in the network is regarded as an entity and is capable of transaction. When a customer downloads an application from a website, the system becomes too complex and might not work without an internet connection. Without a smartphone or Android, installing and running the provided configuration file might not be ideal. The paper also lacks a definition of system architecture and is a theoretical examination.

A Practical Blockchain System for Drug Traceability and Regulation was reported in [13]. The study described how to create a blockchain system for drug tracking and regulation that is scenario-oriented. The researchers presented a drugledger prototype using Ubuntu and C++. Drugs were packaged, repackaged, and unpackaged at various levels. The basic workflow is made more difficult and the track and trace is made more difficult by the packaging, repackaging, and unpackaging of drugs. Drugledger's consensus protocol determines efficiency, therefore it doesn't aim for a 100% increase in efficiency.

The study in [14] used the Internet of Things (IoT), blockchain, and Quick Response (QR) Codes to increase the transparency of the pharmaceutical supply chain. As a business' website, a private blockchain network was utilized. Customers can order pharmaceuticals directly from the manufacturer by scanning a QR code printed on the medication that is connected to the network, forming a smart contract with the business. Only a scanner, such as a smartphone with a QR code scanner app, can be utilized, and the system's delivery costs are very high. Not all customers would be able to avoid paying for delivery. This arrangement is essentially identical to online retailers like Jiji and Konga, where customers pay for delivery of each item they buy.

Kavita et al. in [15] used blockchain technology in developing a framework for the detection of counterfeit drugs in the Pharmaceutical Industry. Their article described how to design a framework CFDD (Counterfeit Drug Detection) using Blockchain technology which is capable of tracing drugs throughout the pharmaceutical supply chain in order to combat the issues of fake medicines. A public and private blockchain types was explained to be made up of the manufacturer, distributor, and pharmacist. Stakeholders/participants will be able to track product throughout supply chain and patient will be able to verify drugs origin. Researchers only makes theoretical analysis. No implementation was demonstrated.

Blockchain technology was also used by the study in [16] to identify fake and subpar medications in the pharmaceutical supply chain. The study described how to create a blockchain-based drug surveillance system. The system prototype was a distributed database-backed DApp. assisting a personal network. One for Ethereum and the other for hyperledger fabric networks were suggested as instances. Every network node has an RFID scanner. The system has a DApp that has a front end and a user interface as well. A number of other assumptions are made in the prototype's design, which could have an impact on execution. System authentication is not possible. Only drug movements that adhere to official distribution channels recognized by the regulatory body will be able to be detected.

The application of Pharmaceutical Drug Traceability Using Blockchain Technology was done by the study in [17]. The article described how to create a system to track pharmaceutical products as they go through the supply chain, from the ingredient supplier through the producer to the patient as the end customer. Data was collected by the researchers through questionnaires and interviews. It was claimed, analysis-based research work that blockchain, operating on Ethereum dApps in a browser, enable decentralized storage of data. The system wasn't put through a real-world test.

Blockchain Technology in Pharmaceutical Industry to Prevent Counterfeit Drugs was discussed in the study by the study in [18]. The main goal was to trace medications from the manufacturer to client delivery using the system. Each drug's impact on the patient will be noted in a database for later use. Only trustworthy parties can join the network and push data into its permissioned blockchain, which was used to store transactions. A distinct number was printed on the product as a QR code. Drugs can only be tracked and traced by smartphone owners, and the unique number was not generated randomly.

The legal implementation of blockchain technology in pharmacy is the subject of the study by the work in [19]. The

authors provided guidance on how to investigate blockchain technology's potential for protecting patients' rights to high-quality medications. The foundation of methodology is an organic fusion of philosophical perspective, general scientific theory, and specialized legal research techniques. The paper only addresses the patient's entitlement to high-quality medications. There is no infrastructure in place to identify bogus medications.

Most of the existing related works are mere theoretical analysis/assessments. Most of the proposals that adopted blockchain technology failed to incorporate the customers' feedback mechanisms or complain channels (through which complains can be directly communicated to the drug manufacturers or the instituted government health agencies). It was also observed that, most authors focused on dealing with issues that bothers on supply chain only (SCM) where each participant can verify the origin of the products on the web, including the patient or customer without authentication, not minding the fact that physical movements of the drug is quite different to web storage and also different to giving customer power of authentication. Furthermore, some of the related works suffer scalability issues, and incurs high computational overheads.

On the part of blockchain technology solutions, I observed that customers do not have feedback mechanism or complain channels either to government or to the manufacturer of the product in the solution provided so far. When a customer/patient get fake product, he/she can contact the manufacturer instead of complain to the point where the product was purchased, legal action can be taken immediately by contacting the producer and the source of the products will be exposed. It is evident that the customer participating in this exercise is of equal importance as fighting counterfeiting or scanning the drug for authentication to eradicate/minimizes illegal drugs

3. THE PROPOSED SYSTEM

The proposed system design involves developing a blockchain and QR codes based counterfeit drug detection system. The architecture of the proposed system is as presented in Figure 1.

This research proposes the use of private/permissioned Ethereum Blockchain technology. Blockchain's cryptographically secure key pairs are used to assign each participant a set of specific activities on the network. Each of the participant will be identified by their unique key pair (private and public) on the network. Private Key which shall be kept in secret is used to sign the transaction.

The digitally signed transactions are broadcasted through the whole network. The key is digital signature like physical signature but is more secure. There are 2 major procedures here in the proposed system, the signing phase and the verification phase. For instance, if a Manufacturer wants to send a message to a given Distributor, the manufacturer; in signing phase, generates a signature using his own private key, he appends the generated signature to a given message, and forward same to the distributor; in the verification phase, the Distributor (receiver) validates the value of the received signature using the Manufacturer's publicly available public key. That way, the Distributor could easily check if the data has been tampered with or not. All these can be formally stated as follows: The sender must make her public key (Ǎ) available so that any participant willing to verify her signatures can do so. The sender selects a Hash function ĥ, then compute the digest document (m) to be signed, using the Hash function, (ĥ) as in equation 1.

$$h(m) = \check{m} \tag{1}$$

The sender then, must apply her private key (a) in conjunction with the encryption function (E), on the message hash obtained in equation 1. This yields her unique signature Ş, for that message, as shown in equation 2:

$$EA\ (\check{m}) = Ş \tag{2}$$

Finally, the sender sends the message whose signature has just been calculated together with the corresponding signature (m, Ş) to the intended receiver:

The next stage is the verification stage, where the receiver verifies the validity of the signature Ş, on the message received from the sender. The receiver must accurately follow the signature verification protocol, by applying a combination of the decryption function Ď, as well as the sender's public key Ǎ, on the sender's signature Ş as represented in equation (3);

$$DA\ (Ş) = DA\{Ea(\check{m})\} \tag{3}$$

$$DA\ (Ş) = M \tag{4}$$

The digital signature algorithm used in the blockchain is the Elliptic Curve Digital Signature Algorithm (ECDSA). The Drug will be considered as the digital asset on the blockchain network (Ethereum), each of them having a unique hash (Unique ID). The unique hash (Unique ID) will be attached to the drug in the form of SnapTags. To access the authenticity of the drug, customers will log into the manufacturer's website, click on his/her desired button/tab option (either the scanning option or the short text message option). Clicking on either of the two options would open up another dialog box, where the customer is expected to supply his name, phone contact, region and finally scan from the embedded Snap Tag App on the Ethereum network. The customer can also take a picture of the company's Snap Tag. This Snap Tag pictures, can then be forwarded via a camera phone with picture messaging capabilities, or even via SMS. The proposed system will offer users both web-based and MMS/SMS interaction interfaces which would be highly user-friendly and easy to manipulate. Customers would be able to forward drug-related queries especially when suspicion of counterfeiting is aroused. Additionally, manufacturers, wholesalers, distributors, and other authorized entities would be able to interact via this system. The implemented system would also be able to give appropriate information on falsified and substandard drugs (toxicology and poisoning). Furthermore, only authorized entities would have access to the developed system, and they would be able to read and write to the blockchain. Indeed, the proposed system is expected to enable authorized participants to encrypt their confidential information before storing or transferring them to the blockchain or to other entities within the network. Only the legitimate recipient would be able to carry out decryption of any kind.

The proposed system would allow manufacturers store relevant data that pertains to the unique identifiers of their partners in the chain, the coding scheme of the product, common name of

the medical product, name and address of the manufacturer placing safety feature, name and address of marketing authorization holder, list of wholesalers who are registered and authorized to store and distribute the drugs. Furthermore, the drug packaging is expected to include anti-tampering mechanisms for detecting cases of content replacement by unscrupulous individuals. Moreover, the proposed blockchain-based counterfeit drug detection system will be accessible at anytime, anywhere and display authenticity and traceability of drugs and drug information.

Hypertext Mark-up Language (HTML), Cascading Style Sheet (CSS), JavaScript, PHP as well as Solidity-Etherum technologies will be used for implementing the proposed system.

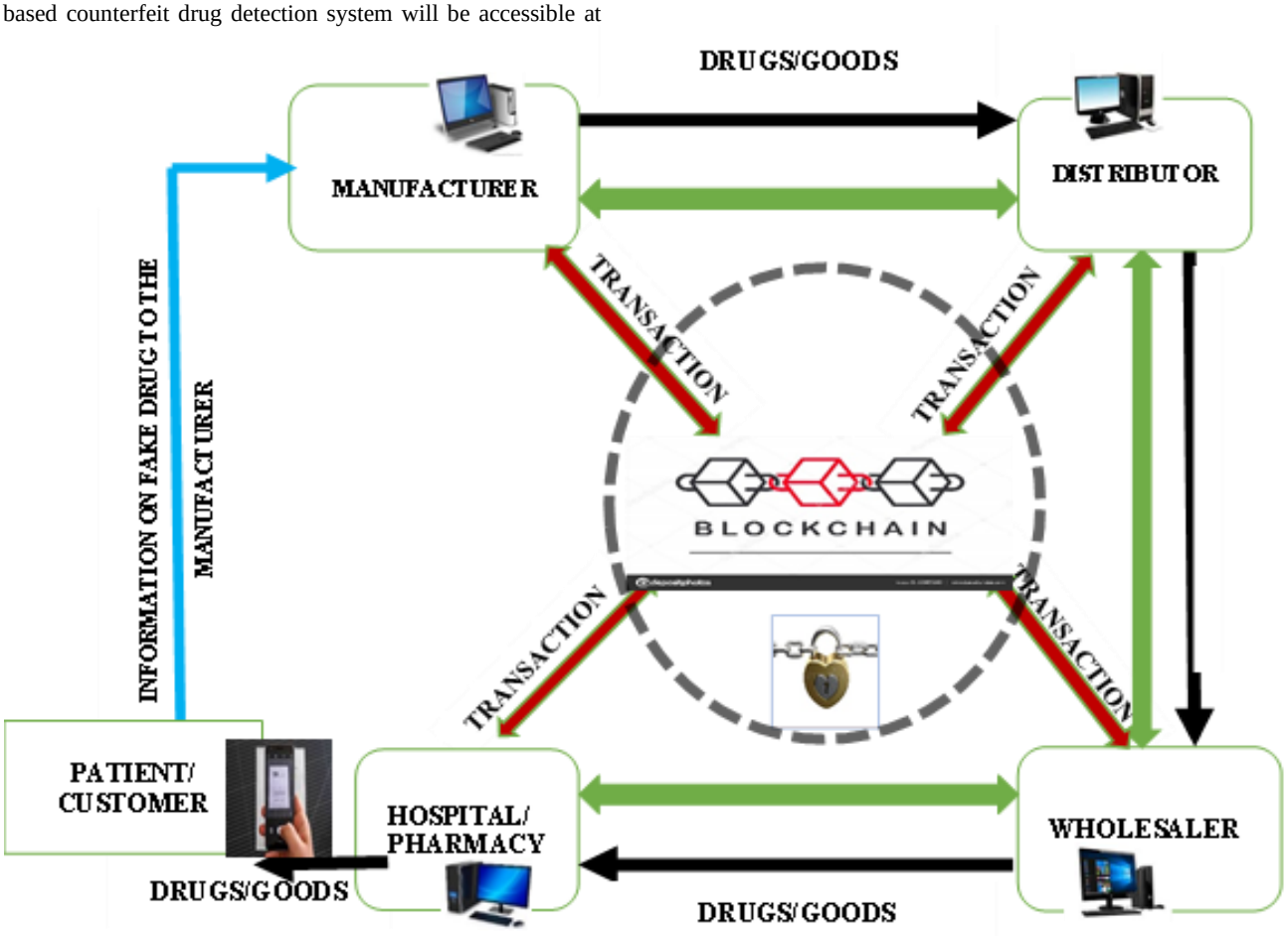

Figure 1: Architecture of the proposed system

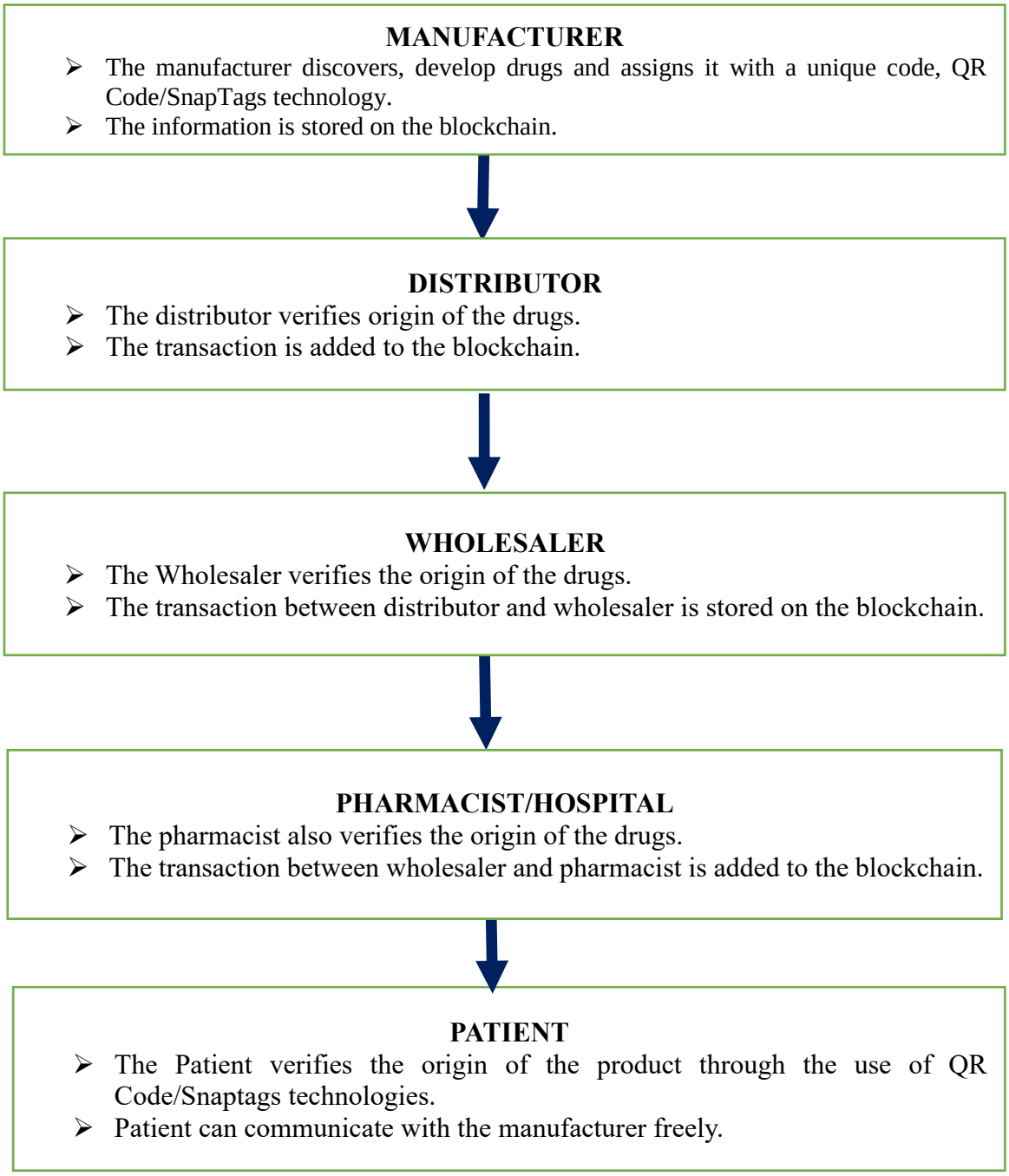

Figure 2: The flow of information between entities in the proposed system

3.1 System Implementation

Hypertext Mark-up Language (HTML), Cascading Style Sheet (CSS), JavaScript, PHP as well as Solidity-Etherum technologies were used for implementing the proposed system

This proposed system realization is divided into modules such as home page, login page, registration page, Dash board, administration panel for adding information, Drug information discipline panel.

The homepage is displayed on the user browser when the site is logged on to. It contains links to all other pages on the website. It contains links sales, confirmations and others.

Another page/interface is the "Registration page of the encrypted Ethereum system: The registration page displayed in Figure 4 allows Pharmacy, Wholesaler, Hospital and distributor to create an account with the drug manufacturer.

The "user login" page is another interface on the proposed system accessed directly. It allows participants to login into their account registered under the drug manufacturer. If the user has registered as a member or to create a new member login account. It takes in user name and password, also when user forget user name or password it can be retrieved by clicking on forget user name tab. The login page displayed in Figure 5.

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Once registered on the proposed system, users (actors/entities within the system) are then allowed to carryout other activities that bothers on the secure/safe transmission of drugs from point of creation to the final consumers, in a bid to prevent any form of crime like counterfeiting.

Figure 5 also presents the drug manufacturer's interface or dashboard showing the various functionalities he can carry out.

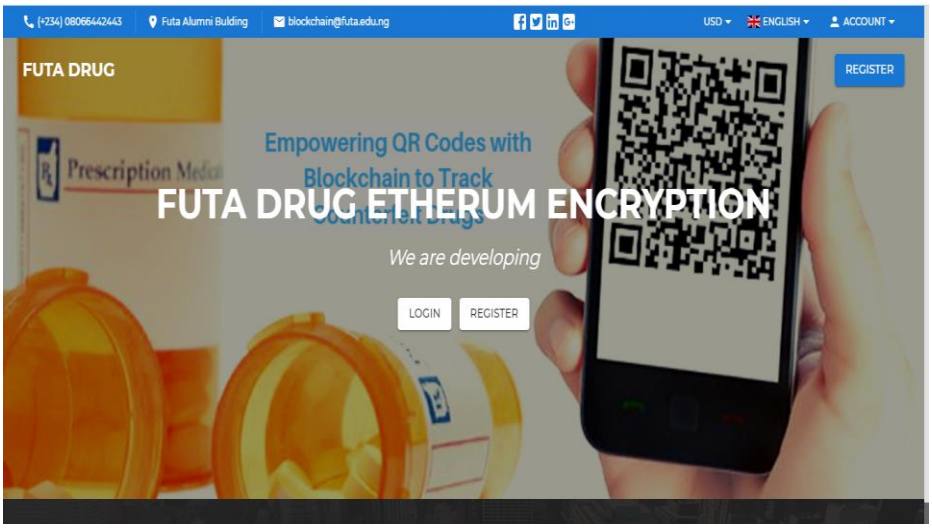

Figure 3: The home page of the Drug Detection Application

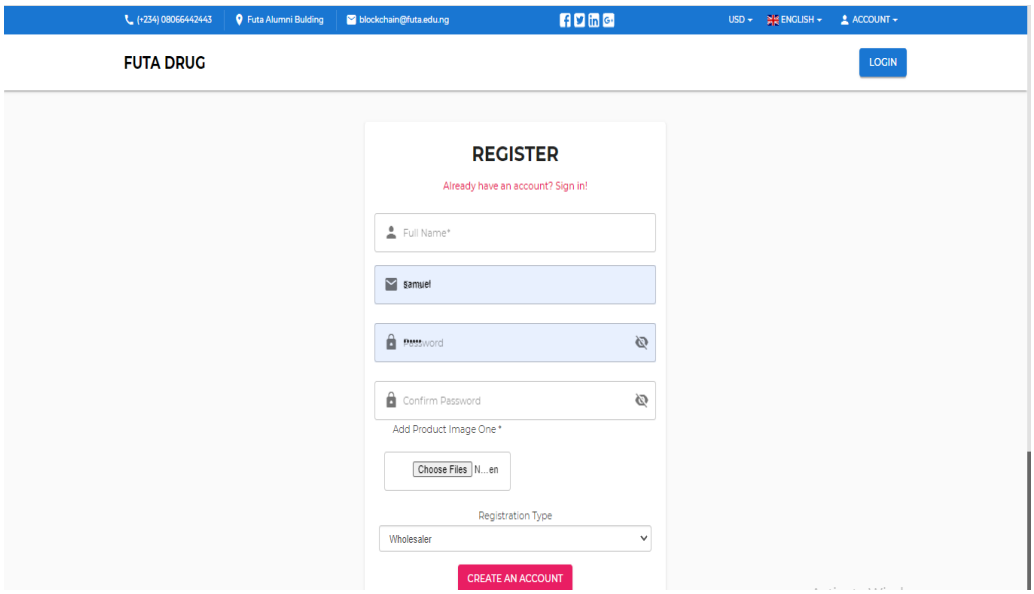

Figure 4: The Users' Registration Page

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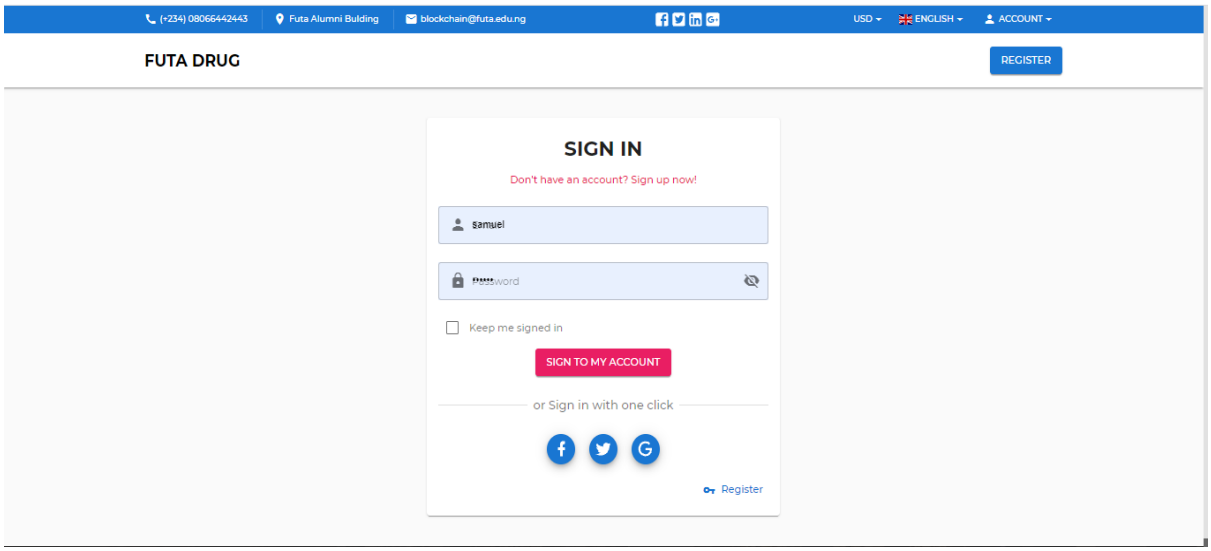

Figure 5: The Users' Sign in page

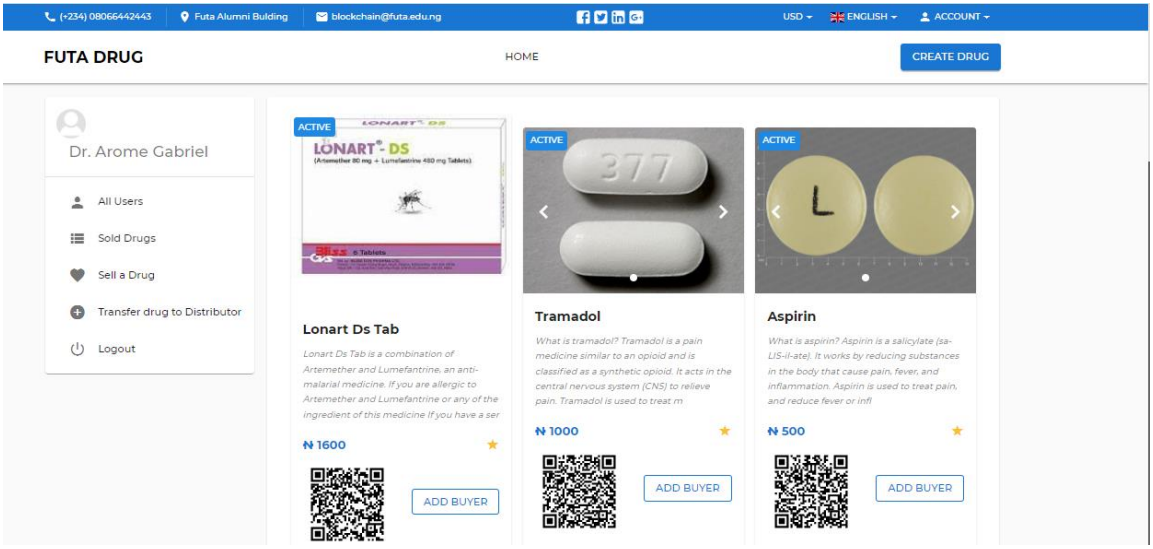

Figure 6: The Manufacturers' Page

Table 1: Comparative Analysis of the Developed System with existing related studies

Author/Work	Smart Contract	Crypto	Network Type	Objectives	Efficiency	Implementation
[11]	Yes	Yes	Hyperledger fabric	Counterfeit Detection & SCM	Low	Partial e.g No power of authentication. Patient need to log in to the network to order drugs online.
[20]	No	Yes	Hyperledger fabric	Counterfeit Detection	High	No
[14]	No	Yes	Not specify	SCM & Drug Detection	Low	No
Developed System	Yes	Yes	Ethereum	Counterfeit detection	High	Yes

Summarily, it is clear from the analysis of the responses obtained from the users that, this newly developed system performs excellently, as it provided services as required by the users, such that a larger percentage would love to use the system again and also recommend the system for use by other stakeholders.

4. CONCLUSION

This study described the creation of a Counterfeit, fake, falsified or sub-standard Drug Detection System, which offers secure online drug verification with elements from the blockchain and smart contracts. The proposed system is made in a way that makes user involvement simple and can also detect phony medications. Users can interact with the system by sending requests or comments to the producers if they suspect that their medications are being counterfeited. Additionally, a separate administration module is provided, which aids the system administrator in managing all drug data, participant information, drug categories, and user requests. The system can be used to operate on handheld devices and should function with any web browser. Additionally, each contact between the user and the system shall last no longer than 3 seconds (the "Access Time"), be used around-the-clock, 365 days a year, and accommodate 3,000 or more concurrent users. It is crucial to remember that lowering counterfeits cannot be done just through technological means. As outlined in chapter one of this project book, other factors that must be taken into account include raising awareness, pursuing legal action against counterfeiters, establishing an effective alert system, and using tamper-proof packaging. Counterfeiting must be reduced and prevented using a comprehensive strategy. Blockchains, however, can be a crucial component of the technology stack used to combat fake goods. Physical products can be connected to a blockchain, which can store every transaction involving the object, using the Internet of Things or unique identifiers/unique ID. Due to the fact that the data cannot be altered, this enables absolute traceability. A further benefit of using private blockchains is that they can boost system confidence, especially if there is no trust in central authorities.

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6. REFERENCES

[1] Briggers, (2018). What is medicine? Retrieved from https://www.medicalnewstoday.com/info/medicine

[2] Hilmas, (2018). Understanding Medicines and What They Do (for Teens). Retrieved from https://kidshealth.org/en/teens/meds.html

[3] Food and Drug Administration Philippines. FDA warns vs fake products. Food and Drug Administration Philippine, (2017). Retrieved from: http://www.fda.gov.ph/announcement/474982-fda-warns-vs-fakeproducts. Archived at: http://www.webcitation.org/6wagexDaQ

[4] Bitchell (2017). Fake drugs are a major global problem, WHO reports URL: https://www.npr.org/sections/goatsandsoda/2017/11/29/567229552/bad-drugs-are-a-major-global-problem-who-reports

[5] WHO, (2017). A study on the public health and socioeconomic impact of substandard and falsified medical products. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO. Retrieved from http://www.who.int/medicines/regulation/ssffc/publications/se-study-sf/en

[6] Interpol. Interpol.int. (2018). The dangers of counterfeit medical products URL: https://www.interpol.int/Crime-areas/ Pharmaceutical-crime/The-dangers.

[7] Tucker J, Fischer T, Upjohn L, Mazzera, D., Kumar M. Unapproved Pharmaceutical Ingredients Included in Dietary Supplements Associated With US Food and Drug Administration Warnings. JAMA Netw Open. 2018 Oct 5;1(6):e183337. doi: 10.1001/jamanetworkopen.2018.3337. Erratum in: JAMA Netw Open. 2018 Nov 2;1(7):e185765. PMID: 30646238; PMCID: PMC6324457.

[8] Bagozzi and Lindmeier (2017). 1 in 10 medical products in developing countries is substandard or falsified: WHO urges governments to take action. World Health Organization Media Center. Retrieved from http://www.who.int/mediacentre/news/releases/2017/substandard-falsified-products/en. Archived at: http://www.webcitation.org/6wagBrWKS

[9] Babar, (2017). Pharmaceutical Policy in Countries with Developing Healthcare Systems. Cham, Switzerland: Springer International Publishing; 2017.

[10] The Philippine Star. Philstar. (2017). Editorial - Fake drugs URL: http://www.philstar.com/opinion/2017/12/05/1765363/editorial-fake-drugs.

[11] Sanghi A., Katakwar A., Arora A., Kaushik A. (2021). Detecting Fake Drugs using Blockchain. International Journal of Recent Technology and Engineering (IJRTE). Volume 10 Issue 1.

[12] Arumugam M., Deepa S. K., Sreekanth G.R., Arun G. (2021). Counterfeit Drugs Prevention using Blockchain Techniques. IOP Conference Series: Materials Science and Engineering.

[13] Huang, Y., Wu, J. and Long, C., (2018). "Drugledger: A Practical Blockchain System for Drug Traceability and Regulation," *2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, 2018, pp. 1137-1144, doi: 10.1109/Cybermatics_2018.2018.00206.

[14] Evans, J. D. (2019). Improving the Transparency of the Pharmaceutical Supply Chain through the Adoption of Quick Response (QR) Code, Internet of Things (IoT), and Blockchain Technology: One Result: Ending the Opioid Crisis. *Pittsburgh Journal of Technology Law & Policy*, *19*(1). https://doi.org/10.5195/tlp.2019.227

[15] Kavita S., Kavita K., Deepak K. S., (2021). Blockchain for Supply Chain in Pharmaceutical Industry: An Approach to Counterfeit Drug Detection. In Convergence of Blockchain, AI, and IoT. CRC Press.

[16] Sylim P, Liu F, Marcelo A, Fontelo P. Blockchain

Technology for Detecting Falsified and Substandard Drugs in Distribution: Pharmaceutical Supply Chain Intervention. JMIR Res Protoc. 2018 Sep 13;7(9):e10163. doi: 10.2196/10163. PMID: 30213780; PMCID: PMC6231844.

[17] Mohana, M., and Gabriel, O., Ern T. (2019). *Implementation of Pharmaceutical Drug Traceability Using Blockchain Technology*. INTI JOURNAL, 2019 (35). ISSN e2600-7920.

[18] Haq I., Muselemu O., (2018). Blockchain Technology in Pharmaceutical Industry to Prevent Counterfeit Drugs. International Journal of Computer Applications. 10.5120/ijca2018916579

[19] Pashkov V. and Soloviov O. (2019). Legal implementation of blockchain technology in pharmacy. 7th International Interdisciplinary Scientific Conference SOCIETY. HEALTH. WELFARE. Volume 68, 2019.

[20] Lokesh M.R., Suhail A. M. N., Saifulla K. (2021). Block Chain Based Supply Chain Management for Counterfeit Drugs in Pharmaceutical Industry International Journal of Scientific Research in Computer Science, Engineering and Information Technology. DOI: 10.32628/CSEIT217122.