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Counterfeit Drugs Detection in the Nigeria Pharma-Chain via Enhanced Blockchain-based Mobile Authentication Service

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ABSTRACT

Drugs has since become a major source of livelihood for Nigerians. It also accounts for over 85% of the total food consumed within her borders. The sector has maintained improved productivity and profitability via a concerted effort to address critical issues such as an unorganized regulatory system, lack of food safety data, no standards in agricultural produce, non-adaptation to precision farming, and non-harmony via inventory trace supports. This study proposes blockchain-based tracer-support system in a continued effort to ensure food quality, consumer safety, and trading of food assets. It uses the radio-frequency identification sensors to register and trace drugs manufacture cum administration process and provide a databank to trace the drug records via the shipment to its distribution centers. To ascertain, if the drug is genuine or fake, the user scans the QRcode via the mobile application API, which then generates feedback. Results achieves the following: (a) presents a framework and roadmap for adoption by the National Agency for Food and Drug Administration and Control (NAFDAC) to ensure pharmaceutical blockchain, (b) show ensemble is scalable for up-to 7500users to yield a performance of 1138-transactions per seconds with response time of 88secs for page retrieval and 128secs for queries respectively, and (c) yields slightly longer time for increased number of users via its world-state as stored in the permissionless blockchain hyper-fabric ledger. Thus, the framework can directly query and retrieve data without it traversing the whole ledger. This, in turn, improves the efficiency and effectiveness of the traceability system.

Keywords: Nigerian Pharma-Chain, Fake/Counterfeit drugs, Healthcare, CORDA, hyper-ledger fabric, NAFDAC

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1. INTRODUCTION

Counterfeit drugs and compromised pharmaceuticals are quite prevalent [1] in Nigeria and globally. Ojugo et al. [2] Pharmaceutical chain is often complex and rippled with various risks for its stakeholders (manufacturers, vendors and patients). A healthcare-focused economy requires all stakeholders' involvement to help resolve the numerous challenges and deliver quality drugs as essential to patients' recovery [3]. Yu et al. [4] Raw materials are transformed into active pharmaceutical ingredient, which are then modifies on to finished product with strict procedure(s). After which, packaging takes place as finished product in distribution centers [5]. They are distributed to wholesalers and other local distribution centers; And lastly, they are distributed to pharmacies, hospitals, and other outlets to ease access by patient(s) [6]. Drugs are targeted agents that yield relief and solution from ailing symptoms in a body [7]. Its components (chemical in nature) that constitutes the drug helps the system to resolve the challenges. Thus, the administration of counterfeit drug yield adverse impacts in the applied body [8]–[10]. Counterfeited drugs have become a global threat cum menace to the pharmaceutical supply chain [11]; And a war that must be won as the cost, risk and losses incurred with counterfeit drugs has risen to billions of dollars, annually and globally [12]–[14].

The practice of counterfeiting is also quite a difficult feat to detect, investigate, quantify, or stop [15]. Factors facilitating the occurrence of counterfeit drugs include weak penal sanctions against such acts, and weak/absence of a drug regulatory authority, etc . Studied have shown that the impacts of fake/substandard drugs is responsible for thousands of deaths, annually in various regions [16]. Residual impacts of counterfeit drugs have yielded significant risks for patients (and their families) [17] – resulting in many forms of losses to include poisoning, treatment failure and even death [18]. Sales of counterfeit drugs rose by 122-percent in 2010 and by 243-percent in 2023 alone [19] such that 1-in-10 medicines supplied in many developing nations were detected as fake/substandard; And, they either had harmful impurities from their manufacturing process, or tested positive with improper dosages of the active ingredients [20]. Nartey et al. [21] 19.1percent of drugs tested were either fake or substandard, and in 2021 – it accounted for an estimated loss of over $900-million in tax revenue annually with over 158,000 deaths [22]–[24].

The Nigerian pharmaceutical supply value-chain consist of the process of obtaining raw materials and chemical constituents, their inherent mixture leading up to the production of a chemical composition called drug [25], packaging, marketing [26], and delivery to patients via its distribution line [27]. Its many stakeholders via careful coordination and regulatory compliance, must ensures that patients receive safe and quality drugs. Pharma-coy must thus, secure and constantly scrutinize this supply chains as means to help mitigate the risks associated with counterfeit drugs [28] – which requires effective management of drugs as inventory, their traceability from manufacturer to target patient [29], resilience of the chain to ensure operability despite faults as encountered, and security of drugs [30]. Even with the worsened proliferation of counterfeit drugs in Nigeria, NAFDAC's vigilance is playing a pivotal role with her frontier policies cum regulations [31]. NAFDAC is yet to attain meaningful strides, as healthcare delivery is provided mainly by the private health sector in Nigeria [32]; And, patients often obtain their drugs via pharmacies (public/private), and retail outlets such as patent shops, illegal vendors, and hawkers [33]. This harsh reality ensures a chaotic distribution network that is managed by both (non)professionals and administered within (un)registered premises [34]–[36].

1.1. The Nigerian Pharmeceutical Supply Chain (Pharma-Chain)

A typical drugs supply value chain can consist of manufacturers, regulate-agency, wholesale(s) and distributors, retailers, and patients with other processes like handling, packaging, distribution, storage, and trading off these products for contract services, and financial portfolios [37]. These processes and the corresponding stakeholders therein constitute a complex, chaotic and dynamic structure whose behavior throughout the chain will impacts the system's performance [38]. The medical and pharmaceutical sector still plays a critical cum pivotal role to ensuring security to millions of lives. Drug safety, quality assurance and security is thus, of critical importance as over 30million Nigerians get sick annually from consumption of counterfeited drugs, which both further complicates their health challenges and can even lead to death from drug poisoning [39]. Counterfeit drugs have flooded the Nigerian pharma-co supply chain and market due to these reasons: (a) there is high reliance on imports [40], (b) unregulated domestic manufacturing [41], (c) lack of inventory leading to stock-outs [42], (d) supply value-chain disruptions, (e) non-destruction of expired drugs with ploy to recoup returns-on-investment [43], (f) corruption within both the supply chain and amongst the various stakeholders [44], (g) weak regulatory framework and policies [45], (h) non-enforcement of the weak regulations [46], [47].

With an unstructured current distribution scheme in Nigeria, government in 2020 established and deployed the National drug distribution guidelines to yield a structured pharmaceutical distribution supply chain. The Pharma-chain had over 350-financially strong importers that are able to distribute to wholesalers, whom will further cascade to retail outlets [48]. A sizeable number of local manufacturers also import their products; while, most local manufacturers hire a distribution team across the country to informally supply to the open market. With more than 5,795 licensed pharmaceutical distributors and vendors in Nigeria, and over 1,675 in Delta State alone, which can be attributed to her nearness to Onitsha in Anambra State that has one of the biggest drug distribution network and wholesale market [49].

Worldwide Commercial Venture is one of the biggest wholesalers in Nigeria and is often used also, by large manufacturers to distribute their products in Nigeria [50]. Its structure is due to change with the adoption of technology and implementation of new regulations that will seek to create regional distribution centers with clearly defined channels of distribution so that manufacturers (and importers) can only distribute their products to specified centers [51]. The addition of this national health program will ensure they distribute also to all specified government hospitals and pharmacies [52]. Such regulated scheme will enforce a more organized structure that will in turn, drastically reduce the proliferation of counterfeited drugs as well as eliminate from the supply chain, unregulated markets and their corresponding distributor(s) as there will be records available on all products and distribution to ease traceability, manageability and access of such records by any stakeholder cum customer/patient [53].

1.2. Pharma-Chain: Fuising Pharmaceutical Supply with Blockchain

The adoption of the blockchain technology to drugs supply value chain can help ensure drugs quality assurance, safety and security [54]. It achieves these via the following: (a) ownership ascertainment of drugs being distributed [55], (b) regulatory control programmes that will ensure drugs quality, (c) government developmental schemes that will help subsidize drug manufacturing and formulate support schemes for pharma-co stakeholders [56], (d) quality assurance schemes to help monitor and

trace records to drug distributors via enforced regulations by NAFDAC within the nation's borders [57], (e) increased performance and productivity via standardized practice and robust implementation of policies and regulations by NAFDAC [58], (f) increased market opportunities through the provision of domestic regulations [59], and (g) enhanced collaboration among manufacturers that will provide both stakeholders and target consumers with immutable records [60] that will help authenticate the drugs being consumed as well as lead to collaboration amongst distributors and manufacturer agents [61]–[63].

Tian [64] integrated the blockchain with a food value chain using the RFID-sensor technology. The food value chain records were tagged using RFID to help easily trace and monitor the food-records, so that activated on the blockchain – it ensured records immutability and integrity with increased user-trust that assured users of food quality, security and safety. Caro et al. [65] advanced the works of Tian via AgricBlockIoT, a sensor-based IoT to yield a decentralized supply chain to yield food records traceability system and help address the inherent challenges to the centralized infrastructure model.

The system resulted in a more robust, transparent, resilient, immutable, and auditable records. Leng et al. [66] used a double chain architecture for the Chinese public service platform to yield a framework that sought to enhance transaction service(s) credibility for users over the platform. The benefits of their system included its ability to manage resources on the platform without knowing the private data of the organization. Thus, ensuring the privacy and integrity of client/user data. Behnke and Janssen [67] investigated boundaries conditions in China, which the pharma-chain must meet in a bid to exist as traceable, manageable and be effectively implemented. Findings showed that their pharma-chain needed to fulfill government regulation boundary conditions.

Bako et al. [68] investigated similar conditions in Nigeria via a regulation frameworks and policies that sought to understand the pharmaceutical supply value chain and its corresponding traceability system. Findings noted the blockchain traceability model resolves the issues of asset recall, safety, quality assurance [65] to yield a realistic strategy to achieve supply chain visibility and eased accessibility by the pharmaceutical chain stakeholders. Akazue et al. [69] investigated the adoption of IoT with blockchain technology. They provided the roadmap for adoption of the blockchain to contribute to the Nigerian food industry and sector by exposing it as a means of electronic management systems and virtualization of processes to achieve food traceability.

1.3. Study Motivation

The study is motivated by the following [6], [70]–[74]:

1. **Weak Regulatory Schemes and Infrastructure**: Even with the constant overwatch and vigilance of NAFDAC, she is yet to achieve any landmark victories due to negative impact via weak policies frameworks and enforcement of regulations on the supply chain. While, this may not be a challenge in itself – it ripples across the Nigerian Pharma-chain with critical issues of poor quality of drugs, resulting in associated cost harm and death.
2. **Unavailability of Records with Domestic Manufacturing**: About 130 companies in Nigeria are licensed to manufacture pharmaceuticals with local firms operating alongside Asian and Western multi-nationals such as GlaxoSmithKline (that leads the market chain with branded drugs sold only to the private sector with their focus on anti-infectives [75], vaccines, insulin and antihypertensives [76]. With other smaller companies gradually expanding to provide

generic products at competitive pricing - Indian firms are proliferating the market chain with lower cost and partnerships with unregistered companies [77]; Thus, these drugs are tagged counterfeit as they have no records; And no available dataset for testing compliance and regulatory control by NAFDAC [78]. Adopting the pharma-chain will seek to curb and minimize such – with the provision of records to stakeholders at needed times [79]–[81].

3. **Corruption**: Tormusa and Idom [82] Greater efficiency is achieved in the healthcare sector of any nation where there is judicious use of both human and financial resources, to serve the sick population. Corrupt practice threatens this as the Ministry of Health in 2022 on the Global Fund for the control of HIV/AIDs in Nigeria – found that widespread of corruption involving program funds as released were running into millions of dollars. Corruption will be minimized with the adoption of blockchain via its record immutability feature [83].
4. **Stock-Outs**: It has become a widespread norm that Pharma-chains experience stock-out, where products are depleted with no means to ease re-stock [84]. This trend can arise due to limited procurement, inefficiency of the supply chain management, inventory-related issues, and so on [85]. Readiness of a primary healthcare center for services delivery is ascertained via its accessibility, eased reachability and availability of essential drugs and medical equipment. With over 2480 healthcare facilities assessed in all the 6-Geo zones in Nigeria, Oyetunde [38] noted that availability of germane/basic drugs were found to be as low as about 25.2percent. Thus, stock-outs of basic medicine in primary healthcare facilities in Nigeria is almost a norm [86].
5. **Distorted Price**: Common amongst pharmaceutical companies is the adoption of medical representative to lobby healthcare experts such as doctors and pharmacists to prescribe their drugs (as alternatives or close substitutes) to patients via offering of financial incentives. These incentives are also based on the quantity of the drugs sold. Thus, this motivates hospital staff to use unnecessary and expensive drugs without strict regulations on drug prescription [87], [88].
6. **Drugs Classification:** In Nigeria – patients can access drugs on the pharma-chain via 3-modes namely: (a) over-the-counter (OTC) prescribed drugs are those a patient orders by themselves without the aid of a prescription, , (b) prescription drugs are prescribed by a physician and can only be handed to a consumer once the pharmacist reads and interprets the dosage, and (c) behind-the-counter prescription are medication stashed in confidence by a pharmacist and not visible to the public, which is only discharged without use of a prescription. Branded drugs are prepared by a registered manufacturers and distributed into the pharma-chain for consumption. Generic drugs are exact replicas of chemical constituents of a branded drug in lieu of ingredients, quantity, performance and pharmaceutical effects. They become close substitutes to these branded drugs, and there is also a growing category of such drugs making ways into the market chain. These, are also counterfeit – except where they are marked as genuine by NAFDAC [89].
7. **QRcode Markings** – In Nigeria, drugs are easily identified with barcode markings on their packaging to ensure authenticity of the drug product. Counterfeit products in turn, also try to replicate such markings of holograms and other distinctive elements attached to the blister foil, film or paper substrate for consumer eased identification. To the untrained eyes, both the genuine and fake/substandard drugs seem identical. Thus, we will adopt barcode encoding on the record-set as a feature/parameter to help classify between genuine and fake/substandard drugs [90].

8. **Administration**: Counterfeit drugs have continued to pose significant obstacle to both health administration, pharmaceutical companies and patient's welfare. To address this, we adopt the study [91] that presents policies on counterfeit technique alongside regulatory protocols rendered by NAFDAC to yield a highly potent anti-counterfeit identification scheme, which is then coded on the blockchain smart-contracts as a unique keyset and state of the drug records [92].

Thus, we adopt the blockchain-based ensemble to render a decision support system that will ensure improved user-trust against counterfeit drugs vis-à-vis the regulatory policies. Our encrypted solution will explore the use of QRcode to scan barcode marking with Relational Database Management System (RDBMS) on the blockchain ensemble. Our choice is resultant of the blockchain's flexibility to yield an optimal solution [93] that will address issues of record immutability [94], to yield enhanced drugs quality [95], assurance [96], safety [97], and recall capability [98]. The system will faster construction of the requisite chain [96] with improved security dimensionality to ensure better model throughput, improved response time to queries and web-server [99], and availability with scalability features [100], [101].

2. MATERIAL AND METHOD

2.1. Existing Pharma-Chain Anti-Counterfeiting Architecture

Drugs from a manufacturer makes many stops prior reaching a patient – which may leave the drug damaged, expired and sometimes, lost. Traceability is a feat or process that allows a user track down the drug supply route from a manufacturer to the patient [102]. This will ease identification of values and timeline vis-à-vis its expiration. Effective anti-counterfeit schemes are essential as they help ensure safety of the patients. In cooperation with law enforcement, private investigations, consumer education, legal actions on illicit traders, and use the adoption of technologies such as blockchain [97], there is a chance to win this war.

Known anti-counterfeiting techniques include [103]–[106]:

1. **Serialization** is divided into: (a) global trade item number (GTIN), (b) serialized GTIN, and (d) data carriers. GTIN is a globally unique identification number used to trade items or services. They are allocated by manufacturers based on GS1 standards and guidelines to ensure the uniqueness of a reference number in each item. It consists of 8-to-14 digits on an outer/inner pack, each fitted with separate GTINs as in figure 1(a). The sGTIN is also a unique number created by attaching a serial number to GTIN of drug. Issued by the food and drug agency (FDA), it helps to ease drug prescription traceability from a plant to package, and distribution as in figure 1(b), and (c) data carriers are used to relate product information in electronic, human readable-forms. They are represented as tags or mark at the source. The most common format used is computer readable such as two-dimensional (2D) bar codes and Radio Frequency Identifiers (RFIDs) [107]–[109]. Security concerns have made it possible to use this technique; However, they can easily be replicated replication of the bar codes that can direct consumers to fake websites. Mass serialization technologies suffer the possibility of having their security tags replicated by unscrupulous drug suppliers such that when scanned – they, send data to one with their application. This gap is resolved via traceability on the pharma-chain. In addition, this offers a security

feature that disallows the duplication of bar-codes produced at the manufacturer's premise [110]–[112].

Figure 1(a). Sample drug GTINs

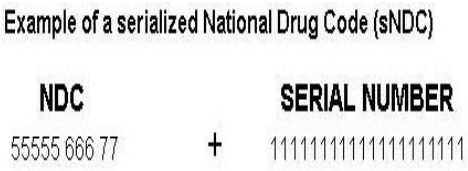

Figure 1(b). Sample sGTIN

2. **Pedigree** is an electronic record containing information about a drug prescription from the manufacturer's plant down to the retailer. The pharmacy attendant must be able to verify that the products specifics match what is recorded in the pedigree. This system has been widely adopted because of the almost zero record keeping failures and less probability of counterfeit drugs involvement [113].
3. **Mini-Labs:** The Kenya Pharmacies and Poisons Board introduced the use of the Raman spectrometers to counter fake drugs in the market. The mini lab equipment is used for testing medicine in the field on the spot. The gadget has the ability of testing content of the medicine directly through the Product's packaging. This is possible since the gadgets use laser light testing. The device assigns specific chemical signatures to the ingredients present in the drug. The board facilitated the acquisition of the special handheld devices to combat the fake drug distribution menace in the market [114].
4. **Holograms** is a 3-layered security features that issues a serial number line authentication with covert features of: (a) ultraviolet-sensitive inks, and (b) scrambled images as its second line of authentication. In addition, the new trend of serialization of holograms now extends this capability with mobile authentication services (MAS) [115] to aid traceability, safety, quality assurance, ownership and security. For this study, we adopt this feature for fusion with the blockchain-based pharma-chain [116], [117].

2.2. Proposed Counterfeit Drugs Blockchain Tracer Support System (DuBoTeSS)

The proposed pharma-chain is a tracer management support system with various dynamism, complexity, and functionality [118]. It presents a management scenario as in figure 2 – which consist of 5-major stakeholder namely: manufacturers (with chemical input stakeholders, and packaging stakeholders), distribution (with wholesale stakeholders) and consumers (private stakeholders and public stakeholders) [119]. Each stakeholder category consists of members that undertakes and plays the same role(s) in the tracer management support supply chain. The chaincode(s) represents smart-contracts on the blockchain framework. Each chain seeks to process the business and transaction logic of the support system, and uploads the palliatives traceability support data of the corresponding stakeholder to the chain. Target consumers are direct (patient) users who can query the blockchain network database for the complete traceability data of drugs [120]–[122].

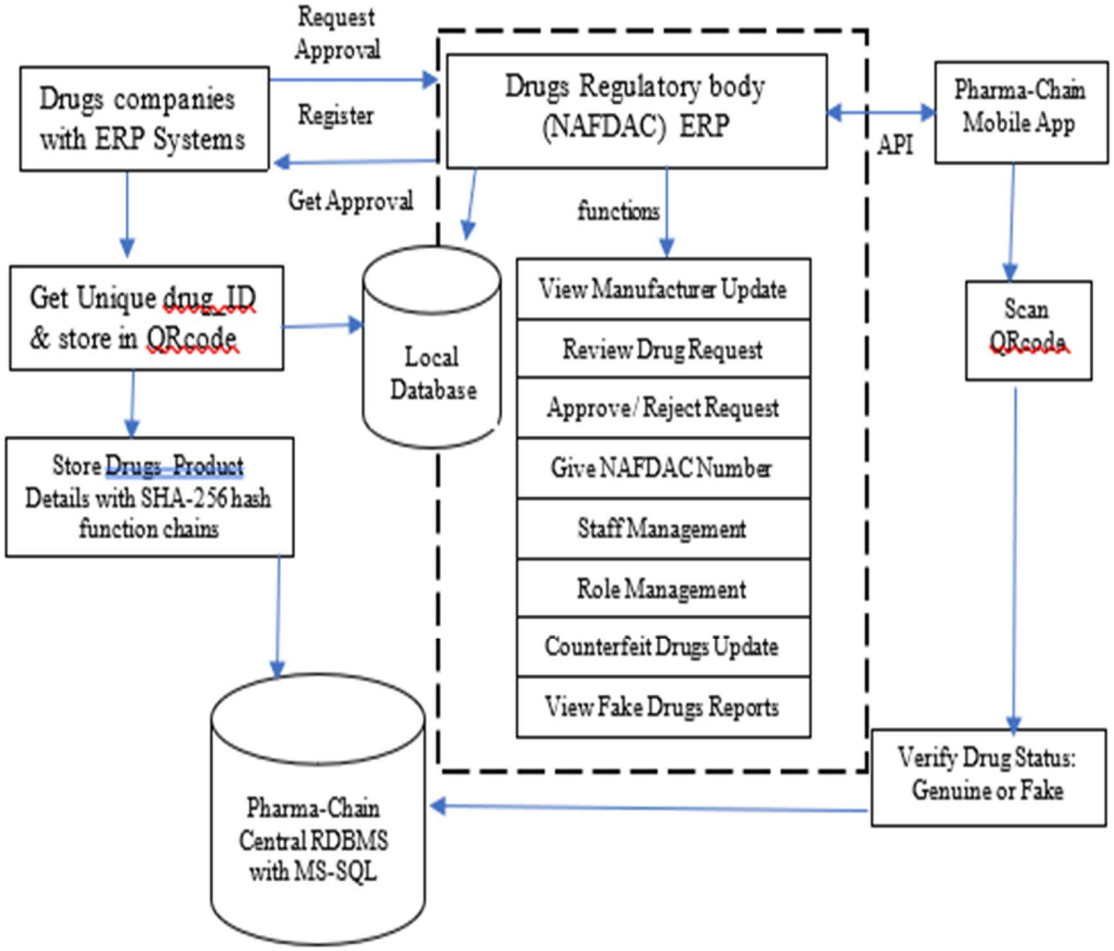

Figure 2. The Proposed Drug Blockchain Tracer Support (DuBoTeSS) Pharma-chain

The chaincode(s) represent stakeholders from manufacturers to target patient as in figure 2. It yields the various drug transition between the stakeholders – detailing how the drugs are distributed (to change their state, as it moves from one stakeholder to another). Also, it uses the smart-contract logic to detail how transactions are executed to regulate their transitions to yields the desired traceability, transparency and efficiency as either counterfeit or genuine drugs [123]. With the requirement analysis, process inquiries, its data design, and major technical activities – we model the smart contracts as a gateway to *k-chains* with capable transaction rules. With registration, each target user/consumer is ceded a public and private key pair to digitally sign each operation on the distributed ledger. The framework uses weights for internal validation and checks so that on detecting anomalies in the record (e.g stakeholders address, transaction batch, distribution ID, etc) – the blockchain will easily flags it [124].

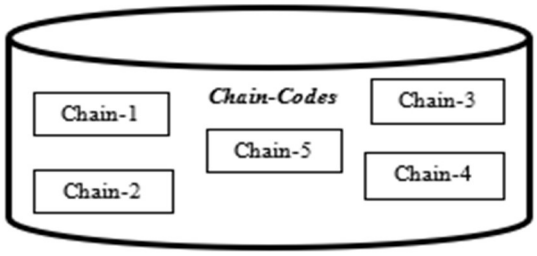

Figure 3. The DuBoTeSS Chaincodes Structure (source: [60])

The smart-contract is explained as thus:

1. **Stage 1: Ledger State** – 'Drug' is represented as a set of properties with assigned values – which creates a unique keyset as well as the state of the palliative. The drugs list is the complete keyset and the state of the drug(s) is initialized as a record in the world state on the hyper-fabric ledger. It supports several states with various attributes that allows the same ledger in its world-state to hold various forms of the same drug, and different types of drugs for use in patient treatments and administration – on the drug supply chain. This – ultimately makes possible the capability of the system to evolve and update its state(s) and structure [82], [125]–[127].
2. **Stage 2: Proof-of-Trust** – With a variety of roles (i.e. manufacturer, stakeholders, target consumers, and users) alongside the varying transaction(s), transition of the drugs among the various stakeholders, how different business interests ascertains who must approve a transaction, and also how individuals state keys work – are enshrined within the smart contract. This means that with/in DuBoTeSS, we set a rule in the namespace to define a business to process a specific/target drug; And later, set another rule that updates all the processed drug assets to portray trust relations of the trade transactions. These concepts can be combined to implement the smart contract [128]–[130].
3. **Stage 3: Smart Contract** – A smart-contracts code initializes all valid states for a drug, and the logic that transitions an asset from a state to another. Smart contracts are essential as they help us set key-business processes and information to be shared across various organs interacting on the network. It defines the various states of a business manages the various processes to move an asset between these states. With DuBoTeSS, the same smart contract is shared and used by the different nodes and by the different applications connected therein. Thus, it jointly executes a shared business data and process. All members of the network must agree to a specific version of the smart contract to be adopted for use [131]–[133].

2.3. Proposed Sequence Activity Diagram

We tested the ensemble by deploying it as an application program interface (API) to be utilized as web applications and mobile apps as in figure 4. To achieve this, we adopt the flask API, and Streamlit interface.

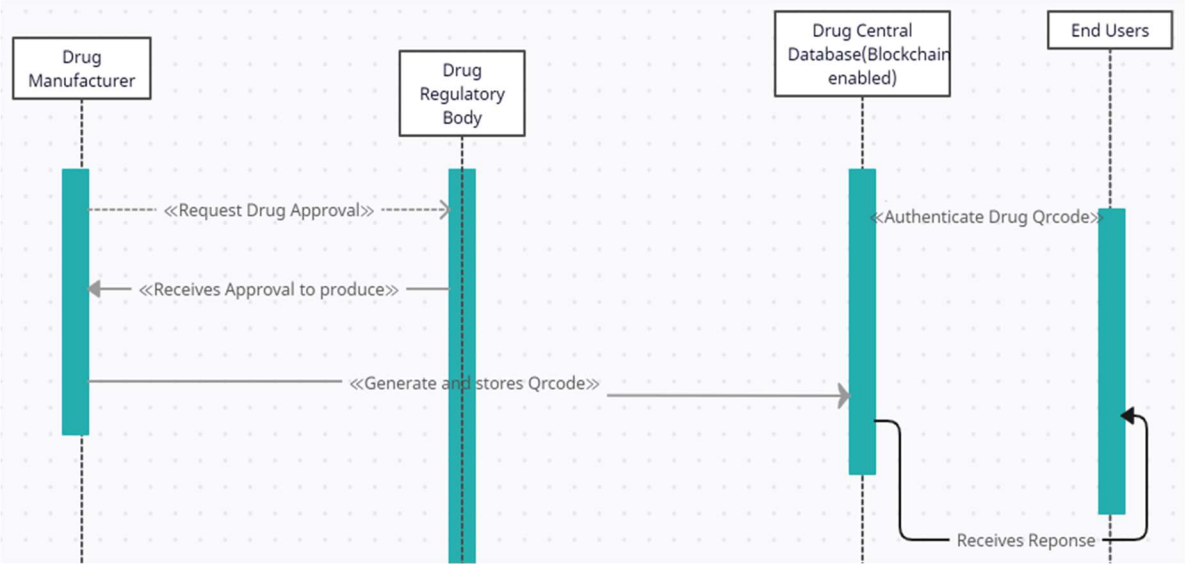

Figure 4. Activity diagram for the DuBoTeSS pharma-chain

1. **Flask:** We hosted the DuBoTeSS pharma-chain via lightweight Python web framework called flask, to ease integration with other apps. It yields the needed infrastructure to transform the ensemble into an accessible, dynamic API. This choice helps to maximize its use across varying embedded ecosystems. Steps to deploy the system includes: (a) initialize specified communication routes and endpoints for the API, (b) integrate the Flask API with DuBoTeSS pharma-chain app to enable it process/accept incoming data, and (c) web app compatibility allows us send HTTP requests and flask ensures embedded devices and mobile apps are all compatible [134].
2. **Streamlit** is an easy-to-use and simple interface used to evaluate the system. It facilitates user interactions, and batches all submitted transactions for analysis. Its other features is that it allows users to input transactions records, which is then sent to the Flask API for processing.

3. RESULTS AND DISCUSSION

3.1. Performance Evaluation for Scalability and Response Time

This performance metric seeks to determine the time interval between a user's request and apps response time to provision feedback to the user. We achieve this by measuring the response time from a query on the https page as in Table 1 – which presents two (2) scenarios namely: (a) a population size of 2500, and (b) tripling the size to 7500-stakeholders. With a population size of 2500-users, the response time of 128secs was achieved for queries and 88secs for https pages retrieval. In addition, with size increased to 7500-users to check for scalability and reachability of the proposed system – there was a longer response time of about 278secs and 187secs respectively for both queries and https pages retrieval feedbacks.

It was observed that querying data tracebacks implies reading data from the blockchain distributed (hyper fabric) ledger that is stored as a world-state database, which records only the key-value pairs to ease records retrieval directly the current key-value(s) of record(s) sought for, without it traversing the whole ledger. This will improve the effectiveness as well as the inherent efficiency in the DuBoTeSS network [135].

Table 3. Performance metrics with DuBoTeSS models

Transactions	Case-1		Case-2	
	Time	Population	Time	Population
Queries	128secs	2500	278secs	7500
Htpps	88secs	2500	187secs	7500

3.2. Discussion of Findings

It provides insights into which characteristics have a bigger influence on overall performance and aids in identifying the most important aspects influencing the model's predictions [136]. The proposed traceability support system uses chaincodes to control query permission(s) and other transactions on its nodes; And thus, protects the target_user privacy data effectively vis-à-vis increasing user trust level. Furthermore, we observed stakeholders' roles were encrypted via SHA256 protocol to secure sensitive data [81], upload to the chain, and prevent data leakage. The ensemble divides stakeholder roles into 5 represented via 5-chaincodes on the distributed hyper-ledger fabric technology to effectively handle the business transaction logic on the blockchain. The model control was deployed via chaincode permission and encryption mechanism to enhance data security and privacy control for the support system traceability model [86]. The resulting model showed a low response time to the query request, alongside stable time convergence for the system throughput as supported by [137].

4. CONCLUSIONS

With the current surge in technological development and the widespread adoption of new technology-driven business strategies, businesses can now operate more efficiently, productively, and profitably. Despite the enormous amount of data generated daily, we have observed that the healthcare industry has always kept up-to-date with technology; However, the adoption of data analytics and data science will bolster the field of medicine. So, for the future of this industry, this study is a positive step and should be improved upon. Furthermore, this research work signifies a paradigm shift in the application of artificial intelligence to mental health diagnostics as supported by [100], [101].

We present a pharmaceutical support system based on a permissioned blockchain framework. Our contributions include: (a) used the hyper fabric ledger for permissioned blockchain ledger to record world-state key values of generated blocks, (b) used QRcode data identification mode to retrieve all drug-records on the framework, and (c) optimized DuBoTeSS system for eased manageability, traceability and administration in Nigeria. The model sought to tackle the counterfeit drugs distribution crisis inherent in the Nigerian pharmaceutical sector – via a high-performance, open-sourced, and user-friendly permissioned chain model with transaction privacy and confidentiality.

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