PRESCRIPTION DISPENSE USING SMART CONTRACT IN SAUDI ARABIA

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ABSTRACT

Medical institutions distribute regulated medications to patients and persist in employing manual documentation methods to record the production, distribution, prescription, administration, and disposal of controlled substances. Consequently, this reliance on handwritten paperwork leads to operational inefficiencies. Of noteworthy concern is the potential for this practice to facilitate the circumvention or manipulation of the system, thereby enabling the issuance of undocumented or non-standardized prescriptions that could potentially harm patients . The central thesis is that smart contracts are a solid foundation for any blockchain development project, by describing the design and implementation of the prescription dispense approach that manages different participants in related sectors. Moreover, designing secure smart contracts required to privacy and security of the healthcare system. This study presents a proposal and implementation for the prescribed immutable and authenticated prescription for patients suffering from chronic disease and need ongoing dispense on regular bases. By employing smart contracts upon blockchain, I attempt to illuminate the benefits of using this technology in the prescription system in Saudi Arabia specifically and the ability of smart contracts to provide security for applications in general. The findings contribute in several ways to our understanding of smart contracts and provide a basis for building a secure prescription dispenser approach that serves the healthcare sector.

KEYWORDS

smart contracts, block chain, prescription

1. INTRODUCTION

Distributes of medications to patients who suffer from chronic diseases in the healthcare sector in Saudi Arabia follows usual methods that delayed patients seeking treatment or endanger them in case the medicine hasn't been refilled on time. In Saudi, The presence of identity verification methods is a centralized identity management system that impedes patient and healthcare provider identification interoperability and authorizes patients to prove their claim for drug dispenses across Saudi Arabia. It also limits the ability to automate prescriptions given to patients who require ongoing medication for chronic diseases like diabetes, hepatitis, and heart disease.
A survey study on chronic disease has been conducted covering all 13 regions of the Kingdom of Saudi Arabia reported that the total prevalence of diabetes alongside hypertension was increment by 13% for both females and males due to the checkup ignorance or delay in obtaining medicine [1].

Traditionally, the medical checkup verification of identity requires physical presence or physical identity and patient identity records are stored centralized differently depending on the treatment plan given or historical record as is also the case in's Local Information System and performs

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local Medication Interaction Checking.This problem constitutes a priority to solve according to National Council for Prescription Drug Programs complex medical diseases such as cancer, hepatitis, multiple sclerosis, and other chronic diseases that may necessitate the use of a specialist drug. There are various routes for processing a specialty prescription, and the current lack of standards means that getting a patient on their treatment regimen might take days, weeks, or even months [2]. There is a growing expansion in adopting smart contracts that build upon blockchain in most sectors in Saudi, especially healthcare. This has been seen in the case of King Faisal Specialist Hospital and Research Centre (KFSHRC) recently completed a blockchain deployment by implementing "a digital credentialing solution" for all residents who use its services. The deployment was carried out through the recently created Blockchain Lab, which has already discovered numerous feasible applications for the technology [3]. There are still very few experimental smart contracts in prescription dispense and managing the interoperability system between the healthcare authority, authorize doctor and pharmacist, and drugs store.The focus of this paper is the demonstration of an experiment that validates a prescription management system using a smart contract and discusses the effectiveness of a smart contract in both security and performance.

The remainder of this paper is organized as follows. The second section displays the background of building our work and related work. The third section is a proposed solution to manage the prescription distribution model. The fourth section presents the implementation of the proposed solution. The fifth section dedicates to evaluating the result and analyzing the security with smart contracts. The last section concludes the work and limitations.

2. BACKGROUND REVIEW

This section presents the building blocks adopted in the prescription management system and the theoretical followed to implement the proposed proposal.

2.1. Block chain

The block chain is a constantly growing list of information. That information is in blocks, and all these blocks are linked together known as a ledger. Each block matches the preceding and following, and the information that the middle block contains is encrypted by an algorithm using a cryptographic function called a hash. This makes this information inviolable. It is a secure, open, and public database. There are three reasons why the blockchain has become so dominant. First, it distributes control and decision-making to a network of entities instead of a centralized entity (individual, organization, or group thereof). Second, given that control is distributed, it is more trustworthy and makes tampering nearly impossible as any erroneous changes will be rejected by the majority of the members in the network. Third, if there is ever a transfer of information from one system to another, it allows for better reconciliation as multiple entities have access to a real-time, shared view of the data.

2.2. Smart Contract

Nick Szabo initially proposed the notion of smart contracts in 1997. A smart contract is a piece of executable code that runs on the blockchain to autonomously facilitate, execute, and enforce the agreed-upon conditions without the assistance of a trusted third party [4]. This leads to minimal transaction costs, but it also introduces various security risks, such as blockchain's intrinsic immutability when paired with a smart contract, i.e. the inability to update the contract's code after it has been placed on the blockchain.Smart contracts are sometimes referred to as "software

applications" to make the phrase more user-friendly and comprehensible, however, they are more related to classes in object-oriented programming than to software applications [5].

2.3. Decentralized Identity Management

To better understand the problems decentralized identity aims to solve as part of that we should take a brief look at existing identity systems; identity has evolved through three distinct phases first came centralized identity which was followed by federated identity now we are approaching decentralized identity. The first two phases of identity user-centric identity took a detour from and back to federated identity it was characterized by efforts including the original open id and browser id that attempted to apply federated identity in a way that gave individuals control even though these efforts failed to gain traction the goals [6].

centralized identity is characterized by using a username and password to sign into websites as the first login mechanism used since the earliest days of computing to log into mainframes passwords have carried forward through the eras including pcs and lands to the internet and the web applied at scale on the web centralized identity creates a massive password proliferation problem. people are forced to have hundreds of different passwords for each site they use assuming passwords aren't being reused if passwords are being reused this creates a security concern as a compromise at one site can result in account hijacking at a different site, in cases where the password is shared this problem has two common solutions password managers and single sign-on password managers give people the tools to manage hundreds of passwords but don't address the problem directly addressing the problem directly brings us to the next phase of identity [7].

federated identity arose as the web and software as a service was seeing broad adoption and the password problem was becoming acute it takes a look at this problem and asks the fundamental questions why do I need a password for every site why can't I sign on once and carry that over to other sites this gives rise to single sign-on or which builds on centralized identity and allows people to use a single password or another set of credentials to sign into multiple websites in this model one website acts as an identity provider.

this login information is conveyed in what is known as an assertion or a token the assertion is digitally signed in such a way that the website can verify that the assertion came from the IDP and that the information within is valid for a website that relies on assertions from the IDP is said to have a trust relationship with that IDP the term federation is a reference to this trust relationship and the fact that it is established between two other.

Move on to what distinguishes decentralized identity is identity is derived from cryptographic keys and identity shifts to a network model using a distributed ledger from a provider model.
Finally, all entities on the network have equal capabilities the network is peer-to-peer.

2.4. Related Work

The recent emergence of blockchain technology has allowed the development of decentralized applications and services. Hence, by illustrating a comprehensive review of existing work addressing controlled prescription management systems issues using Blockchain and smart contracts. Various studies have assessed the efficacy of decentralized identity management such (Y. Liu et al ,2019) by a proposed approach that secures the privacy-preserving of the biometrics identity of individuals using a smart contract, the main concept of this approach is to give the owners the ability to register, retrieve and even revoke the data they own and decided where to store and who and how share it [8]. (Y. Liu et al, 2019) build their system based on registration

and smart contract construction that derive department of a motor vehicle and IPFS as user's personal storage [9]. once the individual construction has been set up he has the privilege to access the smart contract and verified through it. Referred to identity management in the educational sector (Palma et al ,2019) present a proposal for the issuance of a digital certificate using a smart contract that is triggered once the student completes his curriculum.

Moving to medical literature, the consensus healthcare sector to protect the health of the general public is a highly prioritized rule in the health professional's code of ethics [10].Currently, several studies demonstrate the effectiveness of applying blockchain technology in the healthcare sector [11-13].

Other authors (Musamih et al, 2021) provide an end-to-end system that tracks the medicine supply chain that eliminates the manual process of drug production, delivery, and disposal by storing all the necessary information in a controlled drugs regulator (CDR) which governs hospitals, manufacturers, and distributors in parallel with patient and nursing station.

However, (Musamih et al, 2021) fail to fully define a decentralized database system when they still use a centralized database for maintaining all registered actors and controlling drug sales and delivery.

Regarding, (Thatcher et al , 2020) and (He, et al ,2020) both share the feasibility of a Blockchain-based online prescription system, (Thatcher et al ,2020) tend to be more fully online whereas (He, et al ,2020) proposed both online and offline pharmacies.

Table 1: Overview of related work

Citation	Research objective	Governance	Blockchain type	Tool	Access control	Application
Enabling Secure and Privacy Preserving Identity Management via Smart Contract	store an authority's attestation and the transformed value of an individual's biometrics using blockchain and smart contract.	Self-Sovereign	Public	Ethereum	Yes	Identity Management
Blockchain-Based Solution for Administration of Controlled Medication	Management of controlled medication using blockchain and smart contract.	Controlled Drugs Regulator (CDR)	Private	REMIX IDE	Yes	Medical

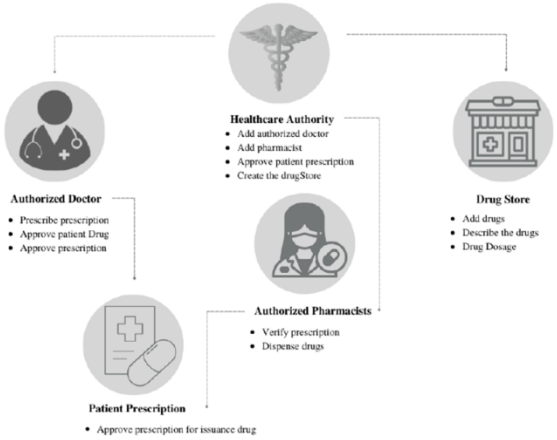
BlockMeds: A Blockchain-Based Online Prescription System with Privacy Protection	An online prescription system with privacy protection.	Three major stakeholders – hospital, pharmacy stores and online pharmacies	Public , Private	IBM Hyperledger	Yes	Medical
Blockchain and smart contracts for higher education registry in Brazil	Enables reliable and decentralized issuance of degree certificates through validation of historical database and triggering of transactions using smart contract	Registry Authority (RA)	Public	Ethereum	No	Education
RxBlock: Towards the design of a distributed immutable electronic prescription system	Enable the development of a PDMP database to provide the necessary attestation of prescriptions, create accountability and reduce prescription overdose for patients.	Prescription Drug Monitoring Program	Public	Ethereum	Yes	Medical

3. PROPOSED SOLUTION

In this section, I proposed a blockchain-based solution for dispensing prescriptions to patients and mutual interaction between the health authority and drug stores using a smart contract.

In addition, Authorized doctors and pharmacists are able to prescribe the drug for patients and dispense it by proving the approved prescription using the patient and drug store address.

There are four roles involved in the proposed solution, which are illustrated in Figure 1



Error!

Figure 1: Participants in smart contract proposal

The first role is the HA which authorizes doctors, and pharmacists in the prescription system and approved the patient prescription given by the doctor to be stored on the blockchain. More precisely, the HA grants permission for a doctor to prescribe drugs for specific chronic diseases and grants the pharmacist to dispense the prescription to the patient.

Moreover, HA is Accountable to manage the process of drugstores and drugs that are provided by authorized specific drugs to specific diseases in a specific drug store to avoid any fraud or manipulation as well it gives HA accurate access to features.

The second role of the participant is doctors. They provide the prescription to patients after diagnosis by providing the medicine related to the disease. For instance, a patient who suffers from diabetes based on his condition will prescribe Metformin twice daily. The third type of the participant is a pharmacist who has the ability to dispense the drugs specified by the doctor and written in the prescription.

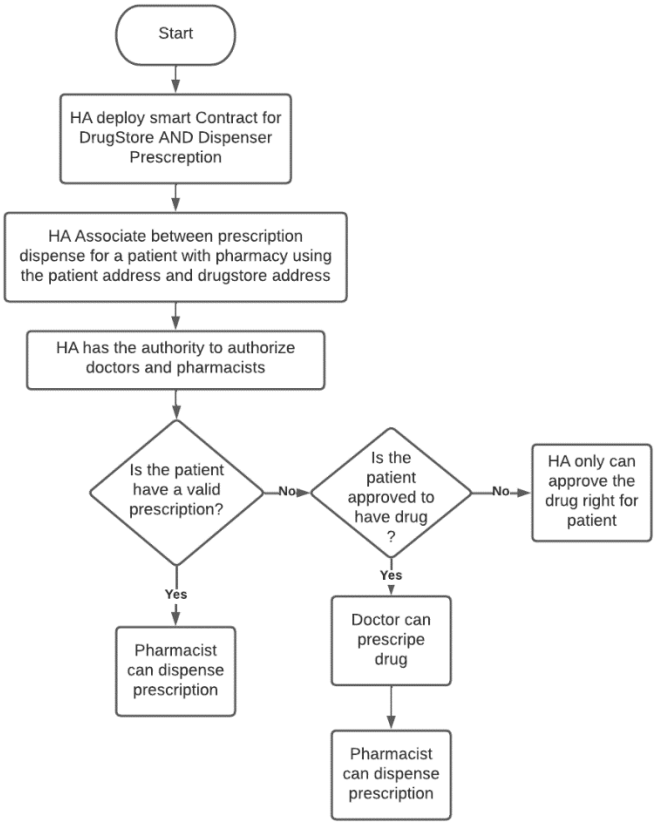


Figure 2: The workflow involving participants and smart contracts in the blockchain

The third role of the participant is a pharmacist and has the ability to distribute the drug to a patient when the patient meets the prerequisite. The forth role of participants is the drug store established by HA with the intent to simulate the presence of multiple drug stores around Saudi Arabia. Last is the patient role which contains the prescription information provided by the authorized doctor related to patient's unique address. The interaction between the participants and the blockchain is implemented by two smart contracts the HA creates. The first smart contract is called the Dispenser Contract and guarantees that prescriptions can only be dispensed by an approved patient and authorized doctor and pharmacist. The second smart contract is Drug Store Factory. Each instance of chronic disease is related to a drugstore contract address produced by inheritance contracts. The reason for that is to simulate various stores across Saudi Arabia.

4. IMPLEMENTATION

To create the smart contract mentioned previously we used the contract-oriented programming language Solidity version (0.8.10) and deployed it and verified it using Hardhat and Raposten testnet network platform supported by Etherscan.

4.1. Dispenser Contract

Dispenser Contract is the first smart contract to be published in the proposed workflow, It is responsible for regulating which doctors and pharmacists are allowed to participate in the prescription system. Moreover, it stores the approved patients in order to prove eligibility to dispense medicine.

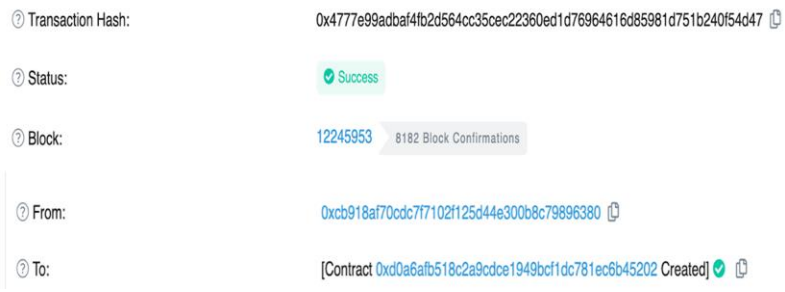


Figure 3: status of transaction of deployed Dispenser Contract

Figure.3 details the transaction hash associated with the created contract and its status which is succeeded.

The last row points to the transaction destination which is the smart contract constructor HA authority.

In order to define the pre-condition for authority to be the only one eligible to authorize the doctor and pharmacist onlyHA modifier guarantee that only HA can authorize role participants, refer to Listing.1.

```
1        modifier onlyHA {
2        require(_HA == msg.sender , "Only HA");
```

Listing 1. A snippet of modifier function

Following this pre-condition now we will define a function for adding authorized doctors and pharmacists by indicating this function to onlyHA which means only health authorities authenticated the doctors and pharmacists and by doing this we accomplish the management of certificated doctors and pharmacists that eliminate fraud or tampering, refer to Listing.2.

```
1 function add To Authorized Doctors (address doctor)public only HA returns (bool){
2        return approved Doctors[doctor] = true;
3    }
4   function add To Authorized Pharmacists (address pharmacist)public only HA
5 returns (bool) {
7 return approved Pharmacist [pharmacist] = true; }
```

Listing 2. A snippet of authorized doctor and pharmacists function

The mapping shown on Listing .3 is essential for holding the mapping of other functions offered by the smart contract Authority which will hold the address of the authorized doctor to a specific address as well as the pharmacist.

same context, prescriptions of an approved patient will be mapping to his address

```
1 mapping (address => bool ) public approved Doctors;
2 mapping (address => bool ) public approvedPharmacist;
3 mapping (address => Prescription []) public prescriptions;
```

Listing 3. A snippet of mapping condition

4.1.1. Dispenser Contract Interaction

The interaction in dispenser contract by adding authorized doctor and pharmacist as shown in Figure 4 and Figure 5

Figure 4: Screenshot of the result after adding the pharmacist address to be authorized

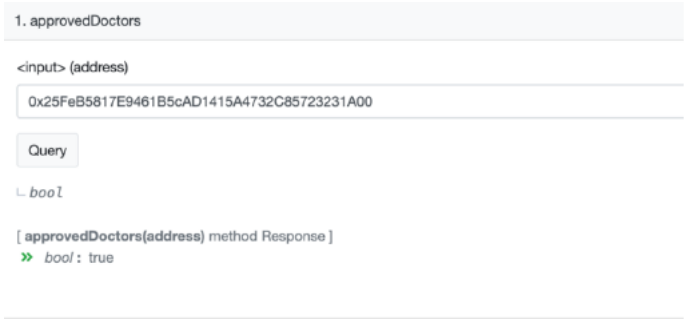


Figure 5: Screenshot of the result after adding the doctor address to be authorized

4.2. Drug Store Factory Contract

The second smart contract to be published by the health authority is for drug stores.

It was important to assume a variety of drug stores and by taking this hypothesis I design a drug store factory that managed and distributed different drug store contracts inherited from the basic one. In Listing.4 the function aims to create a new drug store from the basic one and this can only be done by the health authority, each drugstore has a unique address and index.

```
1 function createDrugStore() public onlyHA returns (address) {
2 _storeId.increment();
3 address _newDrugStoreAddress = address (new DrugStore());
4 deployedDrugStoreAddress.push(_newDrugStoreAddress);
5 drugStoreUintToAddress[_storeId.current()] = _newDrugStoreAddress;
6 emit DrugStoreCreated(_newDrugStoreAddress);
7 return _newDrugStoreAddress; }
```

Listing 4. A snippet of Drug Store new contract generated

To justify this process, storing strings inside the contract is highly cost [14].

Therefore, instead of storing the name of the drug and disease inside the contract, the doctor can add a new drug and description of the medicine as well as the dosage associated with the drug store have been created or exists, see Listing.5.

```
1 function add Drugs (Drug Store _drug Store , string memory _drug Name,
2 string memory _description,
3 string memory _dosage) public onlyHA returns (uint) {
4 uint _drugID = _drugStore.addDrugs(_drugName, _description,_dosage);
5 lastDrugIndex = _drugID;
6 emit DrugsAddedEvent(_drugStore);
7 return lastDrugIndex; }
```

Listing 5. A snippet of add drug function

There are other functions such decrease drug quantity and increasing it, used by onlyHA, by adding this function the health authority will be able to update their drug store factory to suit prescription dispense quantity based on demand. This function will be used each time the doctor adds a new drug to the system by increasing the quantity to be able the view prescription.

```
1 function increase Drugs Quantity (Drug Store _drug Store, uint _id)public only HA {
2 _drugStore.increaseDrugsQuantity(_id); }
3 function decreaseDrugsQuantity(DrugStore _drugStore,uint _id) external {
4 _drugStore.decreaseDrugsQuantity(_id); }
```

Listing 6. A snippet of quantity increment and decrement

4.2.1. Drug store Factory Contract interaction

The interaction in Drug store Factory contract by create Drug Store from the deployed basic smart contract. Each time when we press on write its creating new drug store with unique address and address as shown in Figure 6.

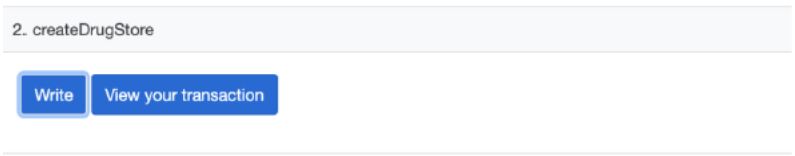


Figure 6: Interaction with creating drug store function.

After the transaction is succeeded, the new address will appear in the logs tab see Figure 7.

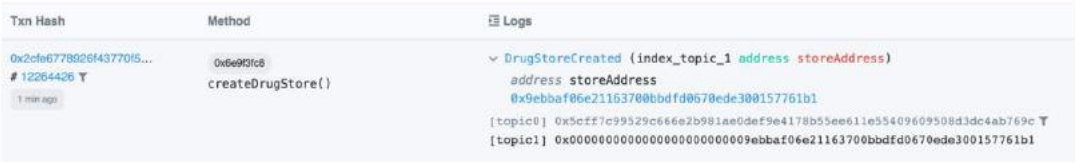


Figure 7: The address of the new drug store

The other functions features the drug store has are add drugs by processing the address of the drug store and drug name and dosage with description as shown in Figure 8

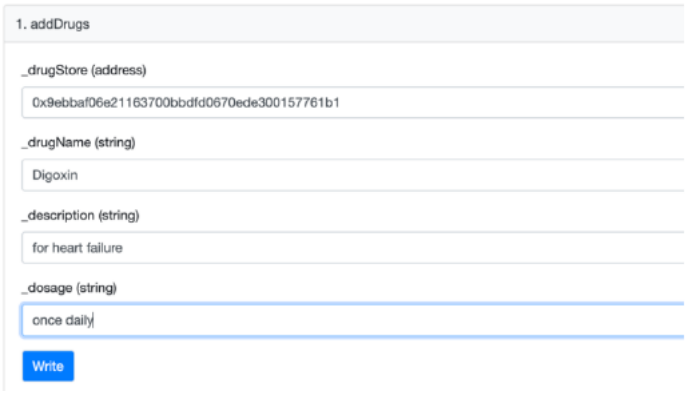


Figure 8: The parameters to add drugs to drug store contract

After creating the drug store and adding drug parameters the doctor will be able to prescribe medicine to patients, done only by authorized doctor to be authenticated see Figure 9.

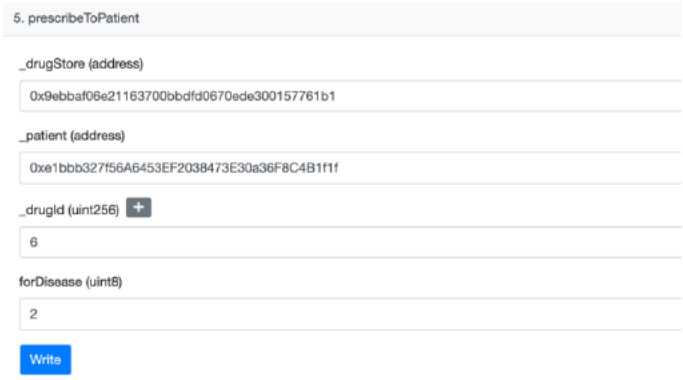


Figure 9: The parameters to prescribe medicine

After approval of the prescription from the authorized doctor role, then we are able to distribute the medicine to patients by processing the drug store address and approved patient prescription as shown in Figure 10.

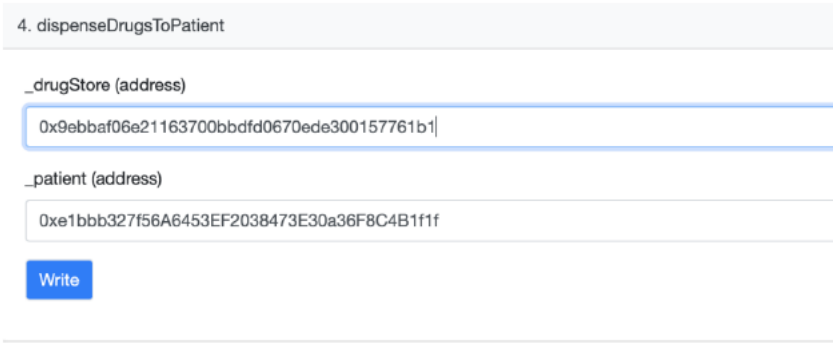


Figure 10: The parameters to dispense drugs to patients.

5. EVALUATION

The purpose of the Experiment on smart contracts in the prescription and healthcare sector was to demonstrate the effectiveness of smart contracts and blockchain in performance and security by examining the speed of the process and testing the smart contract in all aspects.

The gas cost is the amount of gas needed to run the contract, by computing the gas cost of all transactions of both smart contracts we need to minimize it to achieve high efficiency and lower delays in the network [15].

Table 2: Comparison of TGS in each transaction

No	Contract transaction	TGS in ETHR	TGS in Dollar
1	Deploy dispenser contract	0.00000000150000001	0.00000310
2	Create drug store	0.000000001000000008	0.00000206
3	Add drug	0.00000000100000001	0.00000206
4	Deploy drug store contract	0.00000000150000001	0.00000310
5	Add to authorize a doctor	0.000000001000000008	0.00000206
6	Add to authorize a pharmacist	0.000000001000000008	0.00000206
7	Dispense drug to patient	0.000000001000000009	0.00000207

Table 2. compares the transaction gas cost in the dollar which proves the high efficiency and speed of performance of the smart contract in the network.
Following the Merkle Root on the blockchain, meaning the transaction's caller is responsible to provide appropriate values and proofs for any data that the transaction needs to use during its execution which is a certified doctor and pharmacist as well as the prescription for the approved patient.

Smart contracts can verify that the proof is correct, but do not need to store any of that information persistently on-chain only one 32-byte root is required to be kept and updated.
Among the consideration to be taken in evaluating performance is transaction per second (TPS) which is the total transaction that can be carried out on the blockchain in one second. We are attempted to compute it using a timer clock. The result revealed transactions per second are faster compared to the current system for issuing prescriptions see Table 3.

Table 3: The speed of transaction per second in each transaction

No	Contract transaction	TPS
1	Add to authorize doctor	10.52 second
2	Add to authorize pharmacist	5.6 second
3	Create drug store	22.59 second
4	Add drug	31.17 second
5	Increase drug quantity	13.56 second
6	Approve patient prescription	14.05 second
7	Dispense drug to patient	14.63econd

5.1. Security Analysis

In this evaluation we use the Mythx tool to examine the security of the code.
Surprisingly, only a minority of vulnerabilities were found and considered low severity.

ID	Severity	Name	File	Location
SWC-103	Low	A floating pragma is set.	Counters.sol	L: 2 C: 5
SWC-107	Low	A call to a user-supplied address is executed.	Counters.sol	L: 44 C: 792
SWC-107	Low	A call to a user-supplied address is executed.	Counters.sol	L: 44 C: 662
SWC-123	Low	Requirement violation.	Counters.sol	L: 41 C: 24
SWC-123	Low	Requirement violation.	Counters.sol	L: 10 C: 12

Figure 11: Screenshot of vulnerabilities in dispenser contract obtained from My thx

ID	Severity	Name	File	Location
SWC-103	Low	A floating pragma is set.	DrugStore.sol	L: 2 C: 0
SWC-123	Low	Requirement violation.	DrugStore.sol	L: 124 C: 81
SWC-123	Low	Requirement violation.	DrugStore.sol	L: 8 C: 13

Figure 12 : Screenshot of vulnerabilities in Drug store contract obtained from My thx

Figure 11 and Figure 12 show all vulnerabilities related to counter.sol that is imported by the smart contract from external contract added to save integers and count that caused reentrance attack which is when a user executes a method to change state and before the method finish executing they can still call that method again thereby resulting to unwanted consequences [17].

But in our case it will not happen because the health authority is the only one who can execute the contract or the authorized doctor and pharmacist unless these roles are the cause of this attack. The other vulnerability is requirement violation which can indicate one of two possible issues.

First, A bug exists in the contract that provided the external input.

Second, The condition used to express the requirement is too strong.

In our case, the requirement is too strong Considering the OnlyHA is the only role responsible for doing the most interaction with the contract.

This can be solved by weakening the logical condition to allow all valid external inputs[18].

These findings will doubtless be much scrutinized, but there are some immediately dependable conclusions for the effectiveness of using the smart contract in reality and soon the smart contract can provide a significant technological revolution.

6. CONCLUSION

The purpose of the current study was to determine the efficiency of using the smart contract in prescription dispense systems in Saudi Arabia.

This experiment confirmed that smart contracts offer an effective way to cope with prescription dispensing and interact with different participants in the prescription system including the healthcare authority and doctors and pharmacists.

Overall, this study strengthens the idea of blockchain adoption in the medical sector and expands the smart contract approach to prove it's useful for managing any system in any case.
aim to construct a more comprehensive system that appends the ability for the patient to get medication at the push of a button and the ability to identify the closest and available pharmacy by patient location.

The scope of this study was limited in terms of failure to test the smart contract in a real platform such Ethereum and since the study was limited to a testing network (Rapston) , it was not possible to evaluate the results accurately. Also, we were unable to observe the blockchain state due to the absence of distributed ledger block chain.

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