Trusted and Transparent Blockchain-based Land Registration System

Fatmah Bayounis, Sana Dehlavi, Asmaa Azimudin, Taif Alghamdi, And Aymen Akremi

College of Computing, Umm Al-Qura University (UQU) Makkah, Saudi Arabia

Abstract

Fraudulence, cheating, and deception can occur in the commercial real estate (CRE) industry, besides the difficulty in searching for and transferring properties while ensuring the operation is processed through an authoritative source in a trusted manner. Nowadays, real estate transactions use neutral third parties to sell land. Indeed, properties can be sold by the owners or third parties multiple times or without a proper deed. Moreover, third parties request a large amount of money to mediate between the seller and buyer. Methods: We propose a new framework that uses a private blockchain network and predefined BPMN instances to enable the fast and easy recording of deeds and their proprietary transfer management controlled by the government. The blockchain allows for multiple verifications of transactions by permitted parties called peers. It promotes transparency, privacy, trust, and commercial competition. Results: We demonstrated the easy adoption of blockchain for land registration and transfer. The paper presents a prototype of the implemented product that follows the proposed framework. Conclusion: The use of Blockchain-based solutions to resolve the current land registration and transfer issues is promising and will contribute to smart cities and digital governance.

Keywords:

Land registration, Land transfer, Blockchain, Trust, Transparency, BPMN.

1. Introduction

Land registration and transfer is an essential process for governments, companies, and individuals, as it enhances trust among them and works on developing and stabilizing cities. Despite its importance, several cities have not developed this process yet [1]. About 70% of the population, according to a World Bank study, does not possess a title deed [2], which raises the need for specialized systems to manage deeds and their transfer. Many countries have taken an interest in it and have created some advanced systems that make this process easy, simple, and fast. Most of them rely on blockchain technology, as manual and paper registration have many problems. The most prominent countries that have used this technology are Georgia, India, Bangladesh, Indonesia, and Malaysia [3]. Their experiments' success depends on the state's political, social, and technical readiness when adopting new technology. Among the most prominent issues that the blockchain solves:

1. The middleman.
2. Forging, losing, or tampering with land documents.
3. Obstacles to verifying ownership, which may lead to fraud.
4. Save time, effort, and money.
5. One of the biggest problems that governments suffer from is duplicate land registration.
6. Transparency, centralization, credibility, and reliability.

The current paper-based land registration has various issues and loopholes, and it requires a long process that may extend for months just to pass ownership. This system raises a bunch of different problems. For example, the efficiency of coordination between stakeholders and parties such as land records, land surveying, the registration department, and the owner is threatened and may not exist. When dealing with unidentified parties, trust and privacy difficulties arise since the land registry system, or any registry system, involves keeping a sizable volume of registration records, making it challenging to obtain an asset's ownership history [4]. The inefficiency of the registration document storage process may affect the updating and synchronization processes and often lead to a faulty or outdated system, or even affect compatibility with the real ground position [5]. Another issue of land registration is the division and registration of hired estates between the heirs. Nations establish rigorous and rigid inheritance laws that specify how a person's fortune is distributed between their heirs upon death, following their religion (for example, Islamic countries) or status laws. The inheritors need to resort to the courts to allocate the estate by agreement or according to the legal regulations, and then register the land in the system with a new deed. There is a need to implement the principle of transferring the inheritors to the heirs without the intervention of an intermediary, according

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to the country's legislation. There are obstacles, like parties' dissatisfaction with division, the unwillingness of the heirs to own land, and the existence of a will to distribute the land.

This paper introduces blockchain-based solutions to solve commercial real estate (CRE) industry problems according to the country's legislation by protecting the real estate from third parties and intermediaries to ensure that the data remains secure and immutable. The solution guarantees the buyer's right that the property is 100% protected from all illegal cases. Including the government in property verification processes eliminates forgery cases, bribery, duplicate sellers for the same property, and finding out whether there are disputes over the property from the heirs' cases and others. Blockchain creates a competitive environment by reducing financial returns to third parties and holding information for several decades. Our solution, aside from the basic blockchain advantages, contributes essentially to:

- Enabling backend verification of land registration and transfer regarding government rules towards precautions in ownership of lands located in a sensitive area, requested for buying by unwanted people, or subject to the government's projects.
- Increasing competition in the real estate market since the elimination of real estate brokers will lower the price of acquiring and transferring land ownership and enhance the privacy of landowners concerning their land-related activities.
- Grantee the recording of land deeds and all transactions the land witnessed in a transparent, private, non-refutable way.
- Fast and easy transaction completion through the inclusion of predefined BPMN models that determine the pattern of many transactions. Thus, users will select the required transaction type, and the system will guide them based on the BPMN predefined model throughout the following processes.
- Our solution considers forensics requirements regarding record processing to ensure their admissibility [6].

To sum up, the paper's contributions are:

1) The establishment of a transparent and trusted blockchain-based land registration system that enables land management controlled by the government and ensures credibility while avoiding fraud and illegal transactions.
2) The design of Business Process Modeling and Notation (BPMN) models to assist the users in easily accomplishing the land transfer. The BPMNs are translated into a web service and transformed thereafter into smart contracts, which are the only means to communicate with the private blockchain.
3) The prototyping of the proposed model using an open-source platform to improve the easy and cost-effective adoption of our proposed system.

The remainder of this paper is organized as follows: Section 2 presents relevant efforts regarding land management. In section 3, we present our proposed model. Section 4 depicts the different validation processes and results obtained. In Section 5, we discuss the different findings. Finally, we conclude the paper in Section 6.

2. Related works

The papers [7-13] describe the implementation of blockchain technology to solve land registration and transfer issues in several countries, such as India, Bangladesh, Sweden, Georgia, Serbia, Ukraine, etc. Blockchain technology receives increased support from the government to provide privacy and security and information control [14], [3]. The challenge is to avoid duplicate registries of a particular land and property being sold multiple times to different clients, keep a trusted record of transaction history, ensure ownership verification, detect scams and frauds, and participate in the digitization of government services and records.

The authors in [15] discuss the effectiveness of blockchain for land transfer. It concludes that private blockchain is better than public blockchain, but the authors are not convinced about the outperformance of blockchain technology over relational databases. However, the authors in [16] claim that because of its high level of security and straightforward operational structure, Blockchain technology may be utilized to develop smart cities. Similarly, authors in [17, 29] share their beliefs about the importance of blockchain as a replacement for traditional digitization systems. Also, the paper [18] concludes that blockchain solutions are very encouraging and will aid in the

elimination of systemic shortfalls by incorporating both the buyer and the seller into the transactional process, which may challenge the central role of brokers and the management of the ascending bid auctions they perform.

The paper [19] compares the different identity models to identify persons while preserving identity principals' rules. It discusses the lack of existing land registration systems using blockchain systems for effective identity modeling to preserve users' identities. Our proposed blockchain-based land registration system uses a private network, which is a centralized approach managed by the government. Data are only visible to the government, and users could identify the set of data that will be public.

3. Trusted and Transparent Blockchain Based Land Proprietary Management System

The proposed system uses predefined BPMN models to guide the users to successfully complete their transactions, which will enhance the system's reliability and speed up the processing time. Our proposed model encompasses three layers based on a private blockchain network to manage the interactions between the different layers and involved parties. In this section, we will start by providing the BPMN instances of the system-required functions, then we will describe the proposed blockchain-based land registration and transfer architecture.

A. Predefined BPMN models to fastly and easily finish the transaction

We will mention in this section the main BPMN instances showing the system's functions, which are mainly:

- Land Registration
- Buy Land transfer
- Sell Land transfer
- Gift Land transfer
- Inheritance Land transfer

In the following sections, we will describe each BPMN model.

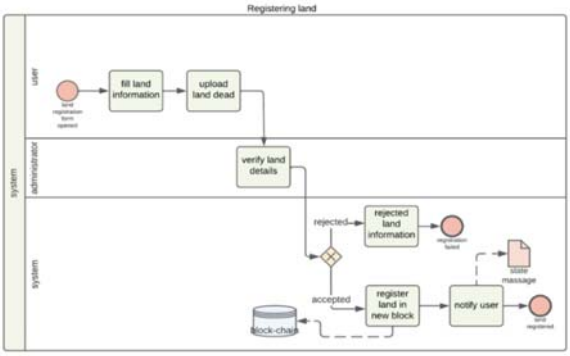

Figure 1. Land registration

1. Land registration model: The "Land registration" process is shown in Figure 1. The user opens the land registration form, fills in land information, and uploads land dead. Then, it is verified by the administrator and different blockchain peers. If all the data are correct, then the land is registered, a new block is added to the blockchain by the system, and the system sends state messages. If errors occur, the system rejects the land.

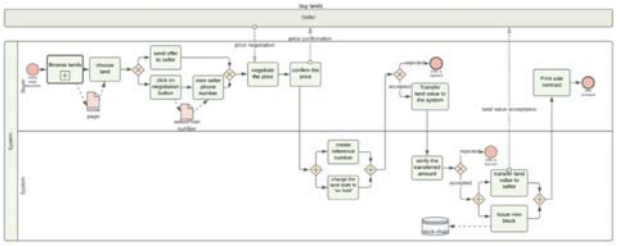

Figure 2. Land transfer (Buy land model)

2. Land Transfer - Buy land model: The "Buy lands" process is shown in Figure 2. The user browses the land list and then selects land to send an offer to the seller. The two parties discuss the price to determine the appropriate price. In the event of an agreement, the system creates the reference number, the land condition is changed to "On Hold," and then the seller transfers the amount if the request is accepted, and the system creates a new block. In cases of rejection, the system informs the buyer and seller. The system creates a contract upon completion of the process of land transfer.

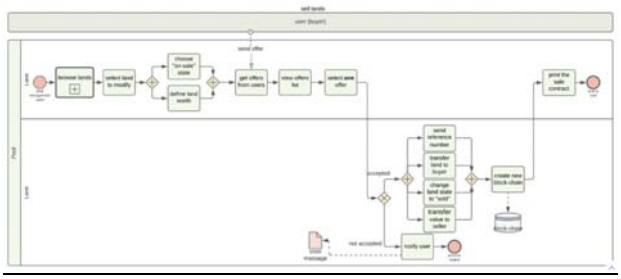

Figure 3. Land transfer (Sell land model)

3. Land Transfer - Sell land model: The “Sell lands” process is shown in Figure 3. The user browses lands and then selects land to change its state to “on-sale”. The system allows the seller to choose the best offer to buy land. The sale process is done by matching the reference number between the seller and the buyer, then the seller transfers the amount if the request is accepted, and the system creates a new block. In case of rejection, the system informs the buyer and seller.

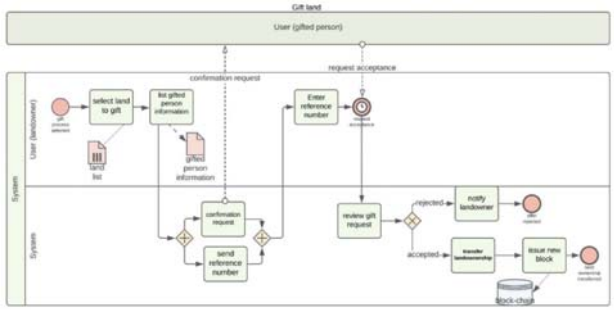

Figure 4. Land transfer (Gift land model)

4. Land Transfer - Gift land model: The “Gift land” process is done as shown in Figure 4. The user chooses land to gift and enters the gifted person’s data. The system sends the reference number to both parties, and if the correct number is received, the system completes the process and adds a new block to the chain. In the event of refusal, the system notifies the landowner.

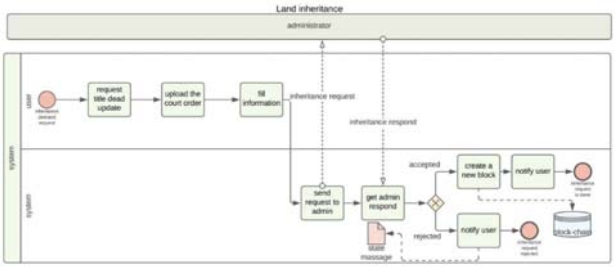

Figure 5. Land transfer (Inheritance land model)

5. Land Transfer - Inheritance land model: The “land inheritance” process is achieved as shown in Figure 5. The user uploads “title dead” and fills in land information. The website sends a request to the admin to verify the validity of the data entered, and based on that, acceptance or rejection is made.

B. Blockchain-based Land registration and transfer architecture

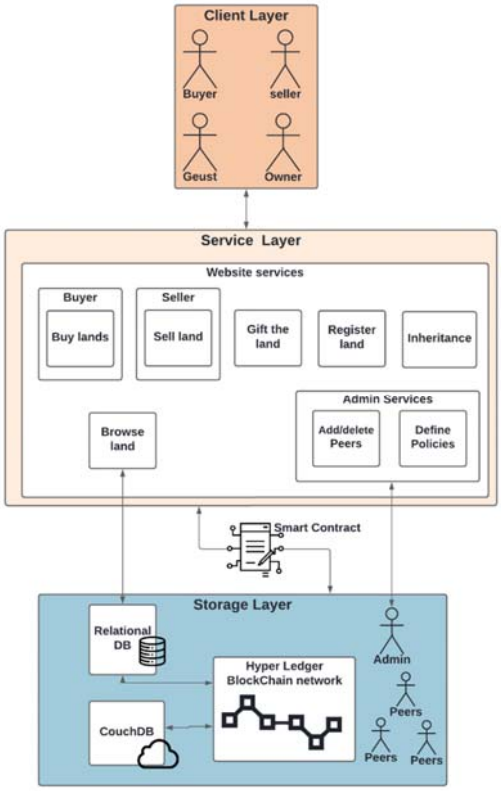

Figure 6. Blockchain-based Land registration and transfer architecture.

We used a layered architecture containing three layers: client, service provider, and storage layers, as shown in Figure 6. Its advantages lie in its high protection and its inability to penetrate the layers easily. The system consists of a service layer implemented as a website to enable clients to register and benefit from the system's features. The main tasks are already described in subsection III-A.

1. Client layer: The clients are the application users, such as citizens aiming to register or transfer land. They only need to register on the front-end website to interact with the blockchain network. The clients could reach several system features described in Section III-A.
2. Service layer: The service layer is a web application that serves as an intermediary between the clients and the blockchain network. It transforms the BPMN models into web-based services where the client can select and complete their queries. The website transforms client requests into smart contracts to enable the interrogation of the blockchain network since smart contracts are the only means to interact with the blockchain network.
3. Storage layer: The storage layer contains the block-chain based network and the relational database that contains duplicate data from the chain blocks.

Our proposed system uses a private blockchain network; more specifically, we use the open-source Hyperledger fabric network to implement the land registration system. Our choice is motivated by the following arguments:

1. The land registration and transfer systems must verify the identity of each participant, so, we need access to government-digitized citizen IDs. Therefore, the network must be controlled by the government to enable access to their assets.
2. The Hyperledger fabric network determines the endorser entities to validate any transaction. In Saudi Arabia, it is essential to include the government to verify if the land is eligible to register according to government-secret policies. Through a private blockchain network, we can enable this feature.

Blockchain: Blockchain is a decentralized digital ledger that preserves data, so it's tamper-proof and very hard to hack, and it doesn't require involving third parties like a bank, company, or government. The Blockchain is managed by multiple participants and has a decentralized database. It's also considered a type of Distributed Ledger Technology (DLT), which means it has a unique cryptographic signature called a hash that records the transactions [20].

Technically, a blockchain is composed of blocks filled with data and associated with the previous block. A new block is created and chained to the previous block whenever new data or a modification occurs. Each new block needs to be algorithmically approved before it's added to the chain, and it has a timestamp that indicates when it has been added. Each block contains a unique hash value and preserves the value of the previous block. If any changes accrued in a block, the hash value changed, and the following blocks indicate the difference when comparing the two hash values of the same block. What makes the blockchain special is that it has distributed duplicates of the Blockchain on what's called a node. Nodes are any electronic devices that contain a replica of the Blockchain, and they are connected to the chain, which gives us transparency [20].

The following bullet points provide an overview of the advantages of utilizing blockchain in land register systems [2]:

- Transparency and ease of access: Every node has a Block-chain replica and views the transaction history anytime and anywhere.
- Increased trust: the fact that the Blockchain gathers consensus before admitting any changes and has an immutable record system improves confidence with users.
- Reliability: Using a distributed database increases reliability since each distributor owns a replica of the data. And if any change occurs, all relevant parties must reach consensus before admitting it. This mechanism is known as the 'consensus mechanism'.
- Cost reduction: The Blockchain doesn't require a third party, and the commission cost is saved.

- Security: blocks in the Blockchain are encrypted using a hash value, which prevents any unauthorized change.
- Availability: due to the synchronized nature of the Block-chain, it helps solve issues like human-made disasters and the availability of information.

Relational Database: In order to speed up land browsing, we incorporate relational databases to just contain duplicate data extracted from the blockchain network. Thus, browsing lands will query relational databases instead of chain blocks, which will enhance real-time browsing and increase the responsiveness of the system. Once the client wants to register, sell, gift, or buy land, the system will communicate with the blockchain network and complete the transaction. Once finished, the relational database will be updated and synchronized with the blockchain data automatically.

Access to the relational database is read-only from the service layer, and any update is only permitted from the internal blockchain component. So, we will not face security issues regarding data integrity. Also, even if the relational database is compromised, land property registration and update are enabled through smart contracts, which means only the data stored in the blockchain is considered during land property change.

Peers: The peers are the persons that verify the validity of the client's requests. They may be formed by any number according to the country's regulations and are composed of lawyers, government agents, and controllers. Peers ensure that the deeds are valid when registering new land and confirm the registered land property transfer. The peers do not know each other, and they may be geographically from different locations. They only receive a transaction randomly and verify its validity. If the transaction is valid, the peer endorses it. If all peers endorse the transaction, then the transaction is accepted and completed. Otherwise, the transaction is rejected, and the client is informed of the issue.

Block data Structure: The data required for each block is extracted from the Saudi Arabia deeds. It consists of the following items:

- Block information
    - Data hash
    - Hash
    - Previous hash
- Transaction Information
    - Transaction ID
    - Previous TX ID
    - Channel ID
    - Endorser signature
    - Endorser public key
    - ChainCode function
    - Real estate unit number
    - Owner information:
        - Owner name
        - Nationality
        - Share/ Percentage
        - Address
        - ID type
        - ID number
    - Real estate unit data:
        - Piece Number
        - Block number
        - Plan number
        - Neighborhood Name
        - City
        - Unit type
        - Deed Number
        - Deed date
        - Court Issued
        - Space in numbers
        - Space in writing Borders: North, south, east, west
        - Length: North, south, east, west
        - Coordinates and corners of the unit Location Map (sketch).

Of course, each block contains the required elements about the block and the transaction information based on the Hyperledger fabric block structure.

4. Implementation and Results

In this section, we describe our implemented blockchain based land registration and transfer system using open-source software more specifically; we use the Hyperledger Fabric block-chain network. Peers, Committer, and Orderer are the three separate responsibilities played by the participants in the Hyper Ledger Fabric network. In the network, the land transfer procedure from one client to another involves peer validation based on the endorsement policy. The orderer places approved transactions into blocks in the correct order. The next stage, known as the committer, receives a group of transactions to validate and commit to the ledger.

A. *Smart Contracts*

The smart contract is a small program stored on the blockchain; the system uses it to automate the process of agreement execution so that all participants can be sure of the results without any intermediate involvement. During the execution of the transaction, the smart contract is triggered by the client and recorded in the ledger. Every successful transaction is recorded in the blockchain ledger, which also keeps track of any previous transactions that contributed to the current values of the object's attributes. Smart contracts require thorough code verification and inspection using security software testing techniques [21] to avoid any possible security bugs since smart contracts are the only means to interact with the private blockchain network [22].

For instance, the code in Listing 1 implements the registration of new land smart contracts. Similarly, each BPMN model is transformed into smart contracts.

```
func(s *LandSmartContract) CreateLand(ctx
contractapi. TransactionContextInterface ,
landData string)(string, error) {
if len (landData) == 0 { return ” ”,
fmt.Errorf(”Please pass the correct land
data”)
}
var land Land
err : = json.Unmarshal([]byte(landData), &
land)
if err != nil {
return  ””,
fmt.Errorf( ” Failed While unmarshling
land. %s”,  err/Error())
 }
landAsBytes, err := json.Marshal(land)
if err != nil {
return ””,
fmt . Errorf ( ” Failed While unmarshling
land. %s”,  err/Error())
}
 ctx. GetStub() . SetEvent(”CreateAsset”,
landAsBytes)
return ctx. GetStub().GetTxID(),
ctx. GetStub().PutState(land .REUN,
landAsBytes)
}
```

B. *Transaction flow between blockchain entities*

The user is supposed to be registered through the linked web application and enrolled by the system's Certification Authority (CA). The system's CA, after user registration, sends cryptographic materials to the user used to authenticate to the network. The land owner (user) initiates the transaction by following the BPMN model to register a new land, for example. The user request is translated into smart contracts received by the different peers who decide to accept (endorse) or reject the proposal. The proposal must be endorsed by all involved peers to continue the transaction; otherwise, the client will be notified of the rejection of the transaction. Through our web-based application, we acquire the user's cryptographic credentials to produce a unique signature for this transaction proposal. The web application then resends the proposal to the same peers and executes it after all peers sign it. The execution of the proposal means the creation of a new chain block containing the different transaction details and confirming the success of the operation.

C. *Blocks and data storage*

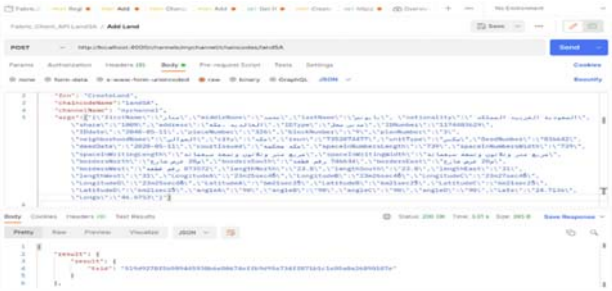

Figure 7. Register new Land

Figure 7 shows how to use the CreateLand method and add its data into the blockchain using Postman; therefore, the user is automatically added to landSA Couchdb. Hyperledger fabric uses CouchDB, which is a document-oriented NoSQL database, to store the block of data. In our case, the block data is stored in the mychannel land$s$a table.

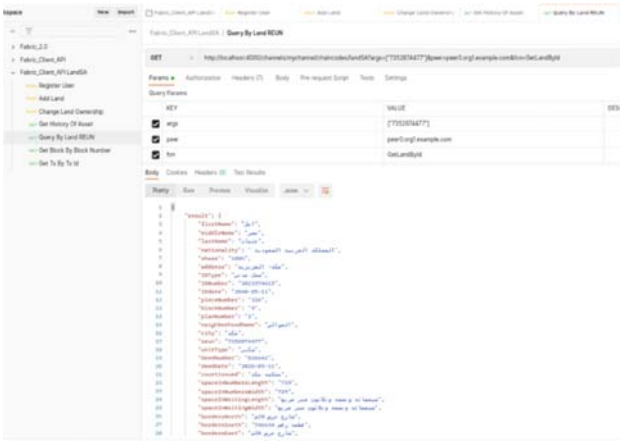

Figure 8. Query specific land

After we CreatLand, we can query land by using REUN(real estate unit number), as shown in Figure 8. We can also get the history of an asset and see all the landowners over time. If we ever had to change the owner of the land, whether by Buying, Selling, Gifting, or Inheriting the land, we would need to use UpdateLandOwner by providing the REUN and the new owner details.

D. Performance analysis

Land registration systems require government control over the different transactions with minimum resources, fast processing, and rule enforcement, which is enabled through the Hyperledger Fabric blockchain.

The Hyperledger fabric network outperforms other platforms, such as Ethereum, regarding latency time and resource consumption. According to many performance analysis studies [23], [24], and [25], Hyperledger fabric always has better latency, and throughput and requires fewer resources. In addition, Hyperledger is a permissioned platform that increases security measures and controls the involved parties better. Thus, we could track any transaction and identify the parties involved in it.

We deployed Hyperledger Fabric 2.0 and created different peers and predefined smart contracts. We use Postman to run the smart contracts. Postman runs smart contracts sequentially, which impacts the response load time. The following figures depict the load response time of ”AddLand”, ”ChangeLand”, ”QueryLand”, and ”QueryLandHistory” smart contracts.

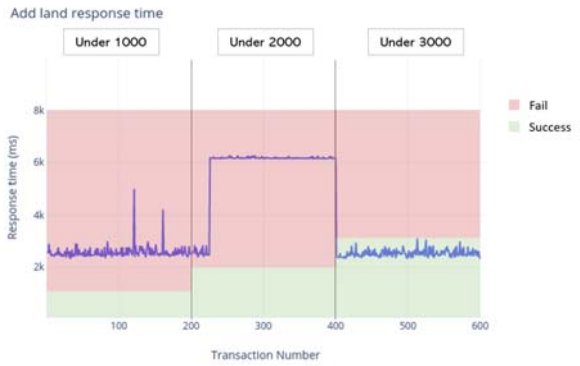

Figure 9. Add land response time

Figure 9 shows “Add Land” transactions tested on different response times 1000,2000,3000. We can see that the transactions tested under 1000ms and 2000ms failed because they took more than 2000ms to finish, while all transactions tested under 3000ms succeeded.

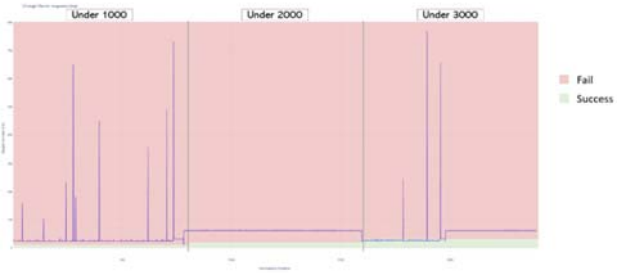

Figure 10. Update land owner response time

Figure 10 shows “Change Land” also known as “UpdateLandOwner” transactions tested on different response times 1000,2000,3000. We can see that the transactions tested under 1000ms and 2000ms failed except for one transaction because it took more than 2000ms to finish, while less than 50% of transactions tested under 3000ms succeeded.

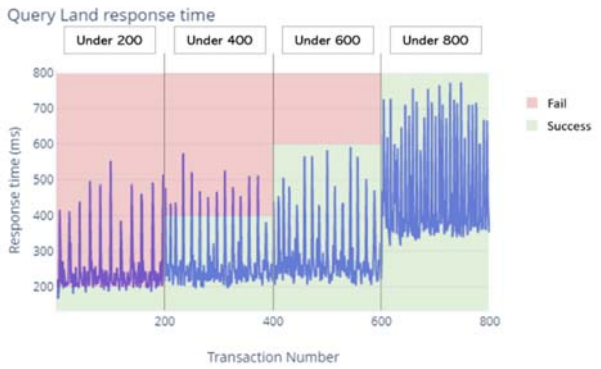

Figure 11. Query land response time

Figure 11 shows "Query Land" transactions tested on different response times: 200, 400, 600, 800. The response time for the query transaction is less than other previous transactions because it is a "Get" type and doesn't change any data in the blockchain. That's why we decided to test it under smaller response times. You can observe that approximately 25% of transactions succeeded when tested under 200 ms, while only 25% failed when tested under 400 ms. On the other hand, all query transactions were successful when tested under 600 ms and 800 ms.

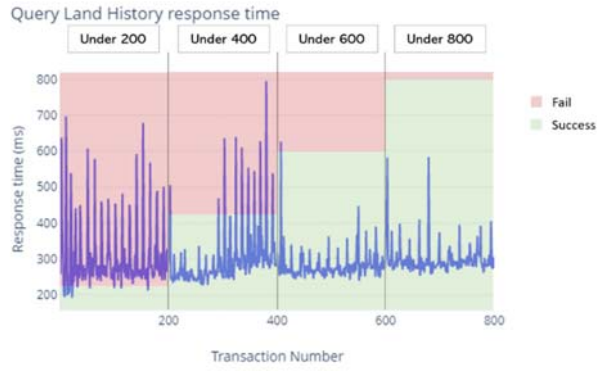

Figure 12. Query land history response time

Figure 12 shows "Query Land History" transactions tested on different response times: 200 ,400, 600, 800. This query transaction is similar in nature to the "Query Land", the difference is that this query displays the land history and views previous owners. You can observe that approximately less than 10% of transactions succeeded when tested under 200 ms but when tested under 400 ms only less than 10% failed. Contrarywise, all Query transactions were successful when tested under 600 ms and 800 ms except for one transaction under the 600 ms test.

5. Discussions

Unlike other solutions suggested by papers [9], [10], and [18], which enforce a transaction fee, our suggested system is run by the government, hence no fees are required. Also, they implemented a two-layer peer verification process in which one layer has a higher level of authority than the other, whereas in our system, peers are on the same level of authority, do not know each other, and might be geographically from different locations. They only receive a transaction randomly and verify its validity to prevent credibility issues. While our blockchain based system stores smart contracts, other systems store an e-stamp certificate [9] or a record of the land ownership transfer to resolve further disputes [16]. An e-stamp involves too many people and is unreplaceable in case of loss, while saving meeting logs seems unnecessary.

Other systems only provide land registration and transfer validation; they don't offer a platform to connect buyers and sellers [7], [9], while our system's suggested platform connects them and enables multiple buyers to debate land without the need to meet in person. To speed up the search and place of offering operations, the LandSA system suggests keeping lands that are offered for sale in a relational database, making it the first system to do so.

Since it's unlikely that a cryptocurrency will be trusted or used for property transactions in the immediate future, like paper [10], due to its volatile nature, LandSA will use traditional payment methods, and clients will complete the payment with fiat currencies. The solution suggested in the paper [10] eliminates the concept of advisories like government agencies, but in contrast, our solution is essentially run by the government to authenticate users and land which is very useful to help eliminate fraud. Islamic law sets out strict and rigid inheritance rules that determine how a Muslim's estate is divided between their heirs upon death. The application of the Islamic system in real estate is limited to Muslim countries, and there are no real estate applications that follow the Islamic system in the distribution of inheritance except our system, which contains the process of sending an inheritance request that is reviewed and validated by the government (peer). In the paper [12], they didn't fully digitalize the land registration process. The landowner needs to visit the land registration office to register the land and then get it added to the blockchain. Our paper focuses on fully digitalizing the land registration process so that users can do it from the comfort of their homes. Paper [13] proposes that after both buyer and

seller make an agreement, it gets sent to the sub-registry office for more verification, which takes more time. Our paper focuses on reducing the processing time and making it more secure and affectionate. In addition, our proposed systems consider, using policies defined by the government, forensics requirements when processing data to maintain their admissibility. Data could then be extracted and automatically processed to extract relevant information regarding specific cases using Ontologies, which are very effective in linking and correlating similar events [26], [27].

6. Conclusions

LandSA is a system that aims to provide a better solution to avoid fraud cases in registering and trading lands, double deeds, and decrease third parties' percentages. At the same time, the system registers the land and then facilitates buying and selling it without intermediaries, all with transparency. Also, our proposed blockchain-based land management system enables the following features:

1. Integrating the land registration process with its trading process is one of the most important goals of this effort. Since the two goals require different requirements, we aspire to provide the optimal solution by integrating the registration process into the blockchain and recording some necessary information for land trading on the RDBs to make the trading process faster.
2. Because the land registration process requires a lot of private information, such as an ID number, a national address, land information, and some banking information, we must increase the guarantee of privacy and security. Hyperledger fabric is the best way to deal with privacy and security.
3. Hyperledger Fabric achieves privacy by isolating private data via the method of private data collection and channel. We chose a private fabric network because lands and real estate units, in general, are fixed units in which ownership changes over time from one person to another, and we need to store all the owners over time. Ordinary databases cannot do that because they may be updated so that previous records may be deleted. As for the Hyperledger Fabric, the transactions are immutable, which means that if any transaction occurs, the record is preserved. Moreover, lands are considered assets, so they must be controlled by the government with Hyperledger's help.

In future work, we aim to increase the security measures against all potential risks and test the system under fixed scenarios. Establishing new metrics for measuring security issues in the blockchain environment is of paramount importance to better analyze threats and quickly respond to them [28]. Then we would like to improve the characteristics of searching for land by specifying the exact location on the map to make the location more efficient and reliable for users. After that, we wish to expand the system further to buy and sell all real estate assets, not just lands. This procedure requires many additional features, such as stress management and efficiency.

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