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Blockchain-based Digital Record-keeping in Land Administration System

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Abstract. Land Administration System (LAS) is a salient infrastructure for any developed or developing country. The LAS is implemented both in digital form (traditional database system) and the manual approaches (paper based documentations). Both of these systems provide monopoly control to an authority which may increase corrupt behaviour in land administration. Again, though the Blockchain technology was originally introduced for keeping a financial ledger; the utilization of this technology can be extended to implement any decentralized computing systems including the digital record keeping and management system. Recent studies found that uses of Blockchain technology in land administration remain new and relatively untested. Therefore, in this work, a blockchain based framework is proposed to develop a land administration system. The proposed framework was simulated in Ethereum blockchain platform; and showed that the framework contributed to develop a secure, reliable, scalable, effective and efficient land administration system.

Keywords: Blockchain, land administration system, mutation, smart contract

1 Introduction

The land administration is one of the most significant branches of any country. The land administration system(LAS) keeps record of real(land) properties, mainly about the location, (historical) ownership, value and use. The LAS also keep data of physical,spatial and topographic characteristics of real property. Thus, the records generated by the LAS are crucial from the social, economic and political perspective[1]. The LAS records should have long term availability, transparency, compliance with proper law[1]. Without proper management the system could be vulnerable to corruption,financial instability and inaccurate. Again, the LAS exists both in manual form which is paper based, and in digital form that uses the database management system. Like any other digital systems, cyber-attacks and information leakage are the key threats for digital land management system as well. Thus, in case of digital land management systems, it is utmost important to maintain the highest level of security against cyber-attack, data tampering, and information leakage.

Data found in LAS regarding physical and legal aspects are often considered to be correct and accurate. The LAS data could get tampered due to data transfer, human error and in some cases by data abuse[2]. Data transparency,verification and

mutation processes are generally handled by some central authority in LAS[3]. Due to this centralization, the rate of abuse and negligence might increase.

A blockchain is a time-stamped series of immutable record of data that is managed by cluster of computers not owned by any single entity. Blockchain technology is introduced in a paper published in 2008 by person or persons under the alias of Satoshi Nakamoto titled "Bitcoin: A peer-to-peer electronic cash system"[4][5]. The white paper introduces Bitcoin as trustless electronic cash system which is not controlled by a third party. Blockchain technology, a peer-to-peer network system that includes stakeholders as the nodes and represents the data as distributed ledger form. Blockchains are shared, distributed and fault-tolerant database that every participant in the network can share, but no entity can control. Blockchain offers security, interoperability and enhanced archival facility[4][5]. According to a recent study[6], blockchain can be defined as *"A concept map of Blockchain which represents that a Blockchain consists of blocks containing messages, proof of work, and reference of previous block and stored in shared database, which is able to perform transactions over P2P network maintaining irreversible historical records and transparency"*.

Now days, Blockchain technology has attracted tremendous interest from wide range of stakeholders, which include finance, healthcare, utilities, real estate and government agencies[7][8][9]. For example, a number of research has been carried out focusing the adoption of blockchain technology in health information in order to obtain enhanced security, interoperability and user trust [10][11]. While a very few studies show integration of blockchain technology in LAS [1][12].However, These studies showed that blockchain stops double spending of transferable entity which is the first and foremost need of LAS.Moreover, the fundamental principles of blockchain and its use in different areas related to record management, introduce several open issues that needs to be explored in case of land administration.The key activities of LAS like the the process of mutation, access to information, proper archival facility are yet to be examined using the blockchain technologies.

Thus, the objective of this paper is to propose a blockchain based framework for developing a secured, trusted and efficient land administration system. To attain this objective,a framework is proposed for LAS considering the relevant properties of blockchain technology and key functionalities of LAS. A prototypical system is also developed based on the proposed framework and then evaluated its performance through simulation.

The organization of the remaining sections are as follows. Section 2 briefly discusses the related work and the summary knowledge derived from the study. The proposed blockchain based framework for LAS is presented in Section 3. Section 4 discusses the simulation procedure and results followed by highlighting the benefits of the proposed framework.Section 5 shows the comparative analysis of our work with existing works and also the summarized research result. Finally, the concluding remarks with future work are discussed in Section 6.

2 Related Works

A number of studies have been conducted on IT based land management system where the database systems and web based technologies were the key concern

to make it automated.For example, Choudhury et al. [13] proposed a web-based land management system for Bangladesh which could scan the paper-based land maps. The scanned images were then converted the images into scalable vector graphics format to store in a database. In an another work, Khan et al. [14] proposed an automated digital archival system for land registration and keeping records. This system incorporated a central database system and the GPS based data collection system for digital archive and retrieval for smoothing the land purchase and sale process. Similarly, Talukder et al. [15] introduced digital land management system which included GPS based land surveying.

A few studies introduced the Blockchain technology in land adminstration systems. For example,in [12] a theoretical representation of a land management system based on Litecoin's public blockchain codebase was discussed that will facilitated to enhance the scalability, privacy and interoperability. This framework was proposed considering only one type of transaction i.e.,transfer-of-value from one user to another. The proposed model was a permissioned blockchain where only a set of preapproved miners could append land records to the blockchain. They built an idea of private sidechains along with public mainchains to store transaction details. However, this article only reported a conceptual framework and no simulation was carried out. Stevanovi et al. [1] proposed a blockchain based Land Administration System to increase its transparency, immutability, security and accountability. They highlighted the main properties of blockchain including transparency, immutability, decentralization and smart contracts; and mapped them into the digital record keeping system of land management.However, this study could not clarify how the genesis block would be created. Also the possible majority attack in Proof of Work algorithm was not solved.

Apart from this, Blockchain technology is introduced also in some other fields for record management that includes: patients record management in E-health system, product delivery management, E-voting system and Banking system. For example, Hanifatunnisa et.al. [16] proposed a blockchain based E-voting System to reduce database manipulation and maintain data integrity. In this article they have introduced, a database recording system on e-voting using permissioned blockchain technology was introduced. The recording of voting result using blockchain algorithm from every place of election ensured the security and transparency. In a study conducted by Ichikawa [10] proposed a framework to develop and evaluate a tamper-resistant m-Health system using blockchain technology which enabled trusted and auditable computation using a decentralized network. Peterson [11] proposed an idea of implementing the blockchain in health information sharing. In this work, a new consensus algorithm introduced to facilitate data interoperability. The solution was theoretically described with some pseudo code of mining.

However, background study shows the importance of blockchain technology in record management as well as land administration system. In sum, grounding on the literature survey a few concerns have been came out. *Firstly,* a number of studies has been conducted using blockchain for record management system in different fields like health care, E-voting, Banking system. *Secondly,* a limited number of studies have been conducted focusing on digitizing the land management systems; while these studies are primarily focuses to minimizing the workloads, save time and also to enhance security to some extent. *Thirdly,* a very few studies have been conducted focusing to LAS using blockchain. The existing

works of land administration system using blockchain have a number of limitations, that includes, for example most of the proposed model/framework are proposed conceptually and did not conducted any validation study; and all the required properties of land management systems were not considered to propose the framework as well as implementing the Blockchain based LAS.

3 Proposed Framework

To design a practical system, the proposed system must resemble closely to the already existing LAS. The framework is proposed considering three concerns. Firstly, the key functionalities of the LAS that includes updating land related information, checking land information, putting in a mutation request and ownership transfer process. Secondly, the stakeholders of LAS, i.e. the land owner, buyers, authority (representative to manage the LAS) and the government. Thirdly, the properties of the blockchain technology.

3.1 Components of the Framework

The two main components of the proposed framework are Block and Node. Blocks create blockchain and the nodes create the blockchain network.The blocks are the data structures that hold information about any land transaction and changes. In the proposed framework the blocks include,
(a) Previous hash- creates link to previous block;
(b) Seller ID- user ID of the seller of the land of this particular transaction;
(c) Purchaser ID- user id of the purchaser of the same land;
(d) Land ID- the ID of the land in question;
(e) Transaction money- price of the land according to market value and
(f) Hash- unique ID for a particular block.

Again, the nodes are the endpoints of the networks. The stakeholders participating in the network act as the nodes. Nodes can be categorized in two classes: i) regular nodes, which can only put up mutation requests and cannot participate in the verification process; and ii) authentication nodes, which are able to authenticate a block, that means it can mine a block which makes them miner nodes. Miners validate new transactions and record them on the global ledger.

3.2 Private and Public Key

Any kind of transaction has to maintain its authenticity. When a user/node initiates a transaction, a block is created with required information. That block is encrypted using the private key of that associated user which can be said as digital signature.Now, if user wants to share information of the block with other user then a public key is generated using the private key which allows intended user to access block's info. The public key expires after sometime to ensure safety. Smart contract is the program where the behaviour of the blockchain is written. Once deployed, the smart contract is immutable and runs unchanged in the network forever. It basically decides the steps required after mining one block. It can directly control the transfer of digital currencies or assets between parties under certain conditions.

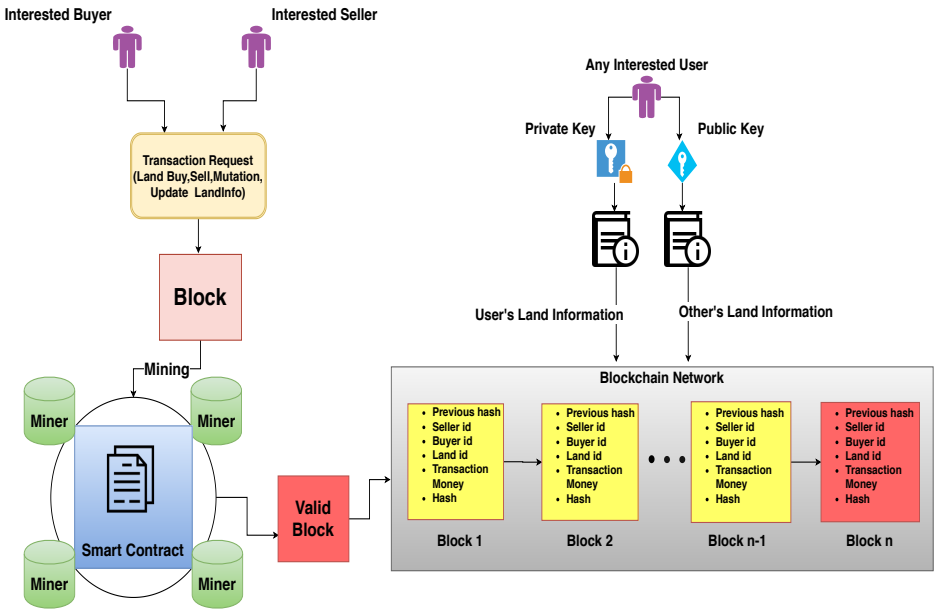

Fig. 1. Proposed framework for blockchain based LAS

3.3 LAS Activities include in the Framework

The proposed framework is presented in the figure 1.The key tasks that required for LAS is showed in the data flow diagram in figure 2.It depicts the working procedure of the proposed system.

Updating Land Related Information- General information which includes measurement, surrounding, infrastructure and price related information might need to be changed from time to time. It is very important that alteration is verified thoroughly. To ensure valid and accurate alteration it will be verified by miner nodes using consensus algorithm. Consensus algorithm[17] makes sure that miners are only able to validate a new block of transactions and add it to the blockchain. The changes are verified against the buyer, seller and also the authorities who changed the information has permission or not, the new information is consistent with existing information and local laws accept the change.

Checking Information- Before purchasing a land any buyer would like to check the land related information. In the proposed system, such information will be encrypted by private key. The private key is only available to the owner of the land. Therefore, to give limited access to an interested buyer a public key can be generated using the private key by the owner which will be provided to the buyer. This public key will allow the holder to only have view access to information which will be specified by the land owner.

Submitting the Mutation Request- The mutation request refers to the initiation of ownership transfer process. In the regular system, buyer and seller create a statement mentioning the information required to transfer ownership of a land

and present that to the local land administration authority. The authority approves the transfer after extensive verification of all provided information[18].In the proposed framework,both parties will file a digital request using their respective private key. After that, a block will be created including all the information regarding the land transfer process. Then, the block will be broadcast to the miner nodes for mining.

Ownership Transfer Process- In this process, using consensus algorithm miner nodes verifies the block created containing mutation information and it is checked that whether the has value of the created block is consistent with the existing blockchain. If the hash value is found consistent, the block will be broadcast in the network. Finally, it will be added to the distributed ledger system and the central blockchain.

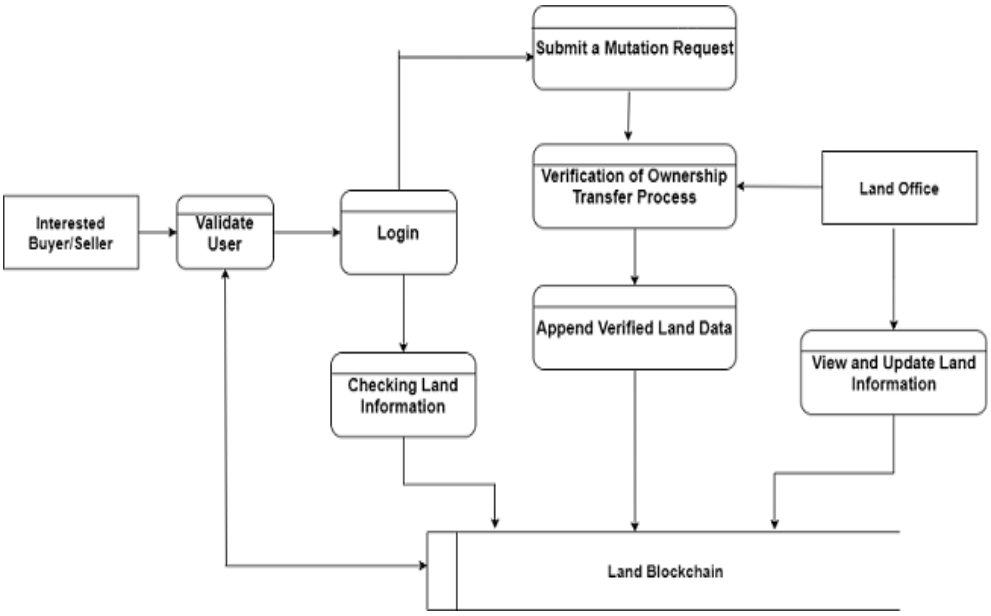

Fig. 2. Data flow diagram of the proposed system

4 Simulation of the Proposed Framework

The section discusses about the environment settings, coding and deploying the smart contract.

4.1 Simulation Environment

In order to simulate the proposed framework in local environment the following steps are followed:

1. *Setting up personal blockchain:* A local personal blockchain Ganache was used to simulate the proposed framework. Ganache by default creates ten accounts and work space to simulate the blockchain.

2. *Setting up development environment:* Truffle development environment creates the local environment and the file system for blockchain project. Truffle is the default development environment tool for Ethereum blockhain platform. To setup truffle in Linux operating system the following command is used: bash *npm install -g truffle@5.0.2*
3. *Opening digital wallet:* Digital wallet allows the accounts in the personal blockchain to connect with the browser and finally to the blockchain network. Metamask is a compatible digital wallet for Ethereum.
4. *Creating project and initiating truffle:* The next step is to create the project directory and initiating truffle environment in the directory. Firstly a directory was created under the project name and then in that directory the following command was initiated to set up the file system: bash *truffle init*
5. *Adding project to ganache:* After the project is created it has to be added to Ganache in order to visualize the current state of the blockchain.

4.2 Smart Contract Deployment and Functions

The first step in creating a smart contract is declaring the contract itself. Solidity programming language, which is specialized for blockchain development, treats the smart contract similar to *class* as in object oriented programming language. After creating the contract, vital operations of the framework such as, updating information, checking information, submitting mutation request and ownership transfer mentioned in section 3.2 can be included as the member of the contract.

The member methods and block structure of the smart contract are as follows:
i. Block: The blocks are basically a type data structure. In solidity it is declared as *struct*. They are created to hold the information of a transaction.

ii. Posting a free land for sell: Initially after survey process if any land has no real owner it can be posted for sale by the survey office or any government agency. The sale function is named *createland* and it's procedure is presented as pseudo-code in algorithm 1. The function receives land location and land price and as parameters and after validation of the parameters the record is created and added to the record data structure.

Algorithm 1 Add New Record of Land

1: **function** CreateLand($\_landLocation, \_landPrice$)
2: Require $landLocation.length > 0$
3: Require $\_landPrice > 0$
4: $landCount = landCount + 1$
5: $lands[landCount] \leftarrow$ *Add New Record of Land*endtate emit *LandCreated*

iii. Posting a land for sale by its owner: If the owner of a land wants to sale the land it can be posted. For this a *landforsell* function is called. This function makes the land block available for potential buyers to create the buying block and put up for mining. The pseudo-code of this is presented in algorithm 2. The function takes land id of the of land for sale. The purchase flag is set to false to indicate it is up for sale.
iv. Purchase land and mutation: The purchase land function is the function that actually performs the mutation operation.The mutation process is refered as

Algorithm 2 Change Land Status For Sell

```
1: function LandforSell(landID)
2:     Require Land ID is valid
3:     purchase flag ← false
4:     emit LandforSell
```

purchase land here. Once any buyer puts in a mutation request *purchaseLand* function gets called. The mutation block created by the function is uploaded via metamask for mining in Ethereum. The process of mutation is shown as a pseudocode in Algorithm 3. The method requires *land ID* as parameter. Upon validating the Land ID all the relevant information is fetched from the database and a block is created. That block is emitted to etheruem for mining and if found valid the mutation is completed and the block is added to the blockchain.

Algorithm 3 Purchase Land

```
1: function purchaseLand(landID)
2:     Require Land ID is valid
3:     CurrentLand ← Fetch Land from given Land ID
4:     Owner ← Get the Land owner
5:     Require Account Balance land Price
6:     Require Land is not Purchased
7:     Require Seller and Buyer are not same
8:     CurrentLand.Owner ← Change the Owner
9:     Transfer the fund
10:    purchase flag ← true
11:    emitLandPurchased
```

4.3 Ethereum cost and gas fee

Deploying smart contract in Ethereum and triggering any event creates a block. To mine that block and add to the chain upon verification needs some computing power. In Ethereum platform the computing power is measured as *gas fee*. Also some amount of digital currency is required which is *Ether*.
Computing power for five core operations of our framework has been calculated. They are: deploy migration function, deploy LAS smart contract, create land function, purchase land function, land for sell function. The histogram in figure 3 shows the gas use for each function. The color codes for each function is described in the figure.
Figure 3 showed that deploying the contract consumes the maximum amount of computing power. Compared to that the other functions need considerably lesser amount of computing power. The next histogram in figure 4 represents ether costs of the same functions.

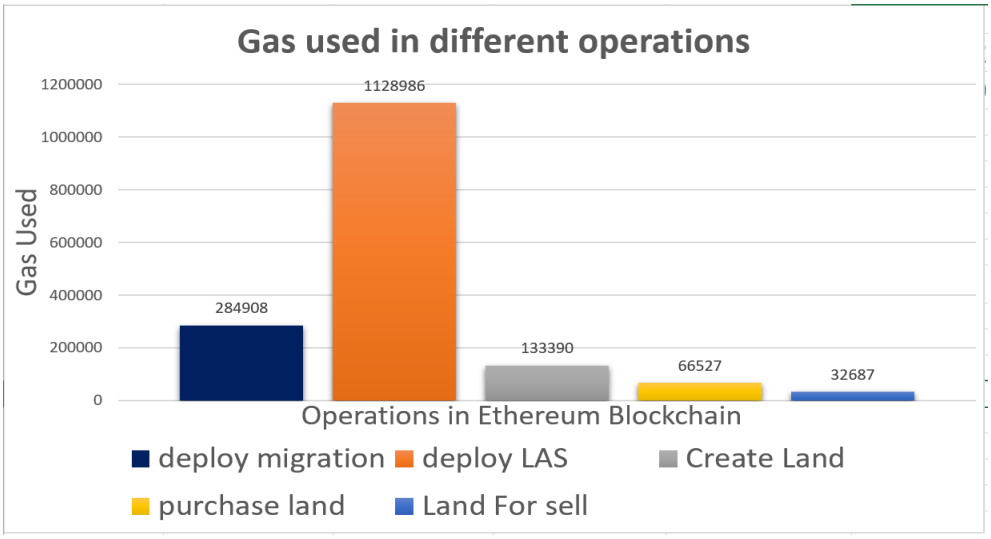

Fig. 3. Gas used for each functions

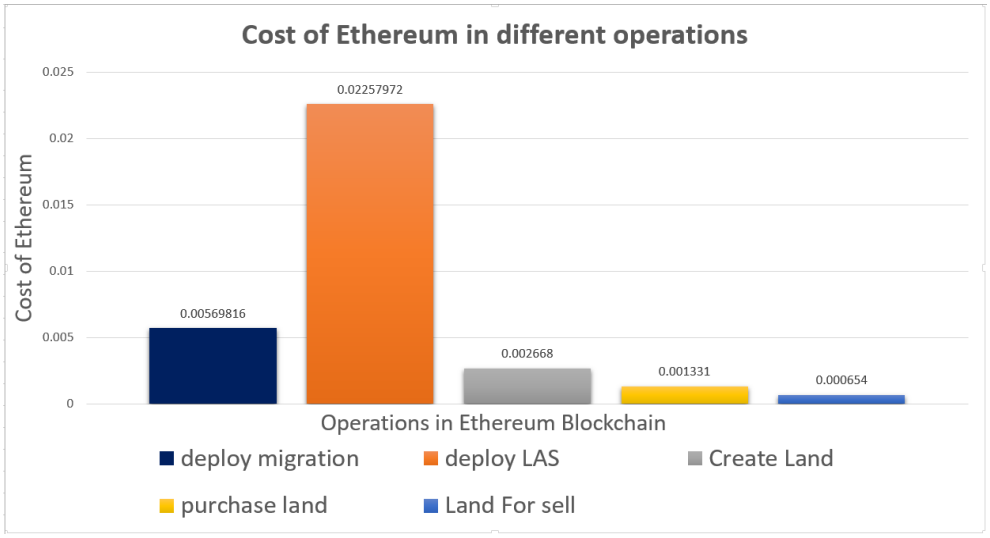

Fig. 4. Ether used for each functions

As observed in the figure 3, deploying the contract consumes most power, as a result this is the most costly function. The other functions are less costly and among them adding a new land information costs the most.

4.4 Execution Time

Fig. 5. Execution for each functions

The graph in figure 5 shows the execution time of land for sell, land create, land purchase functions for several test cases in milliseconds. It is evident from the test vs time graph that purchasing land takes the most amount of time and it spans around 900 ms. The second most execution time is taken by creating land which spans around 300-400 ms. Then the lowest execution time is taken by land for sell function.

5 Discussion

In this research, based on the proposed framework a local web application was created using Ganache to host the local blockchain. The computational power and execution time required to execute each function of the proposed LAS is also discussed in prior section. The simulation results showed that the blockchain based proposed LAS system would bring the following benefits:

First, the proposed framework offers extensive security features to LAS. Consensus algorithm used in the proposed framework ensures that no invalid block is added to the blockchain; and any tampering to the chain will occur a series of change operation which alerts the system immediately. Moreover, since the proposed framework generates private key for each end-user, it also ensures that a user can access only his/her information.

Second, the proposed framework is simulated in an ethereum blockchain platform which uses proof of work consensus algorithm that ensures consistency among the participating nodes[19]. Thus, any change of information is verified and then updated in every local copy of the blockchain using the proof of work. As a result,

the data of the proposed system remains consistent and accurate.

Third, Blockchain also serves as an efficient archival system[20] and enhanced trustworthiness, data integrity and supports multi-factor verification [21], which are the foremost need of land administration system as well. Again, the proposed framework stores change log in the form of blocks in the chain that also ensures the trustworthiness of the system.

Fourth, the computational power needed to mine each block is significantly lower than uploading the smart contract. As the framework allows selected few nodes to be the miner block, thus less computational power is required for mining. The deployment of the contract needs a large amount of computational power, however, this occurs only once in the systems lifetime. For example, as shown in figure 3, the *createLand*, *purchase land(mutation)*, *land for sell* showed less computational power.

Finally, some operations like posting a (land) sale notice and creating a new land block showed an average execution time, that is, less than 400 milliseconds. Again, a comparatively higher execution time is showed for the *land purchase(mutation)* (see Figure 5), it is around one second (1000 milliseconds) that still can be treated as relatively faster. This features can increase the acceptance of the system to end users. Thus, the proposed framework offers great scalability and user reach as well.

6 Conclusion

In this paper, a blockchain based framework is proposed for land administration system. The functionality includes (a)updating land related information, (b)checking land information, (c)submitting the mutation request, and (d)transferring process of land ownership. The proposed framework is evaluated through simulation. The simulation results showed that a secure, reliable, effective and efficient land administration system could be developed based on the proposed framework. Though, few existing work focused to the blockchain based land administration system but these studies did not consider all possible functionalities of LAS as well as did not evaluated through the simulation system, for example, Patil et al. [12] introduced a concept of *landcoin* that includes only the ownership transfer process. Considering all the aspects it can be said that the proposed framework brings uniqueness and contribution to design and develop effective land administration system. However, the performance of the system in real time transaction is yet to be tested. Again though the memory management of this distributed network is a prime concern,but this research did not explored the memory management. Our future works will focus in these directions.

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