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Design of Land Administration and Title Registration Model Based on Blockchain Technology

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Abstract
Land administration and title registration system is the system for storing land title information and managing transactions involving land titles. Due to the sensitivity of land issues, land administration and title registration system should be strong to avoid any document forgery, available all the time, and take a short time to complete tasks. Thus, this study aims at designing a model for such system based on blockchain technology. The proposed model is designed using UML diagrams and then tested for verification using statistical usage models (Markov chains). The proposed model integrates the Integrated Land Management Information System (ILMIS) with factom and bitcoin blockchains which enables encryption of information from ILMIS to get the fingerprint information of each land title and store it to the blockchains. The model further encrypts the land information from ILMIS when needed and then compare it with fingerprints from blockchains for verification. Such implementation of the proposed model will help ILMIS to have the capability of providing tamper proof for stored data, providing the self-notarization mechanism, and availability of evidence for the land title from distributed databases. Furthermore, the society is expected to benefit from this study as the time and cost for registering land title will decrease and the possibilities of a piece of land having more than one owner will not be there.
Keywords: Blockchain, Bitcoin Blockchain, Factom Blockchain, Land Management System, Model Design.

1. Introduction

Blockchain is an electronic ledger of digital records, events, or transactions that are hashed cryptographically, authenticated, and controlled through a distributed or shared network of participants using a group consensus protocol. The blockchain is distributed among millions of computers with mechanisms for validating transactions that utilize a group consensus protocol (Donegan 2016).

Blockchain technology is the way of looking differently the inner functions of the normal database which gives the power to a single authority like administrators who have the ability to change the information in the database if they want to. This power can be abused by unfaithful administrators. Normal database suffers the problem of single point of failure and makes them depend much on backups in case of failure and when both running database and backups are harmed can bring very serious problem (Peters and Panayi 2015).

Research findings by Peters and Panayi (2015) show that the blockchain works differently compared to normal database whereby the information is encrypted and stored in every node connected to the network and eliminate the possibility of having single point of failure, fraud, and corruption.

According to the Land Act (1999) Part V, Sections 19-23, three land occupancy rules are identified; the constitutional or granted rights of occupancy, the customary right, and other informal rights. In all rules, the rights to access, develop and occupy land are granted by the government under leaseholds of up to a maximum of 99 years.

Currently, the land registration process is done through a Certificate of Customary Right of Occupancy (CCRO) for village land, and Ministry of Lands, Housing, and Human Settlement Development for urban land or reserved land. This process has got some challenges, like taking too long to complete, corrupt government officials, registrars of titles and village council or registering several owners to the same land title, etc (USAID 2010; Kironde 2009; Huber *et al.* 2013).

The weaknesses in current land registration and administration process have led to the loss of lives, loss of properties, loss of homes, and increasing of misunderstanding in the society. Based on different research like Kironde (2009), Kombe (2010),and Silayo (2013) and a news report from Nyanje (2014), people die, others lost their homes and properties due to inefficiencies in current land registration and administration process.

There is an effort that has been made to tackle the challenges facing land registration and administration process in Tanzania. The government via the Ministry of Lands, Housing, and Human Settlement Development came up with a strategic plan for the development of an Integrated Land Management Information System (ILMIS). The system is expected to be completed in 2018. After completion of the system, the government is expecting the increase of security, availability and reliability of land information. Also, the issuance of land title to take 40 days instead of six months of the current system (Lwandiko 2015).

There are some challenges which will still remain unsolved even after the completion of the ILMIS. Firstly, ILMIS is the centralized system which means there will be a problem of single point of failure. Secondly, ILMIS will not give complete immunity and auditability to the records stored in its database. This means that users who have total control of the system such as administrators can change the records without being detected. Thirdly, the issuance of land title in 40 days is still a very long period of time and this is due to the long process of notarization. If the system would have the capability of providing self-notarization, the issuance of land title can take few minutes instead of more than a month.

This research aims at designing a model for secure and robust land administration and title registration system based on blockchain technology, which will help in eradicating the weaknesses showed in current land registration and administration process. Land administration and registration systems with blockchain technology are implemented in Ghana, Estonia, Georgia and Honduras. Although they are still in their initial stages, there are challenges and strengths which have already been experienced. The challenges in all countries are the lack of awareness of blockchain technology to the society and difficulties in the registration of titles which are still in conflicts. The strength of the systems is the ability to time-stamping transactions analogous to virtual notarization, disaster recovery as the system does not rely on a single data center, and recording of details in a tamper proof and immutable environment (Dobhal and Regan 2016; Anand *et al.* 2016).

2. Methodology

The requirements of the proposed model were gathered and then summarized from 200 respondents whereby 180 were land owners and 20 were land officers from Dodoma municipality which is the capital city of Tanzania. Interviews and questionnaire methods were used to gather the requirements.

To design a model proposed by this study, factom and bitcoin blockchains were used. The reason for using these blockchains is that bitcoin's blockchain is the most trusted data proof store available, but on another hand, it was designed for bitcoin transactions only. Factom blockchain gives the ability to different applications to access the bitcoin blockchain for non-bitcoin transactions.

The model was designed using Unified Modeling Language (UML). Visual Paradigm for UML software tool was used to develop the model. The model was tested for verification using statistical usage model which is also known as Markov chain.

3. Model Design and Testing for Verification

3.1 Bridging the Gap

The model integrates ILMIS with the factom and bitcoin blockchains to bridge tempering proof gap. ILMIS now will have the fingerprint of information stored in its database which will be distributed in millions of computers all over the world. The fingerprint of information will act as immune against unauthorized changes of information stored in ILMIS database. ILMIS will have the capability of providing self-notarization which will minimize the number of days for issuance of land title.

3.2 Development of the Model

A. Requirement Specification of the Model

Requirement specification is very important part of software engineering; it lays out functional and non-functional requirements. Functional requirements specify the functions that a system or component must perform. Non-functional requirements specify criteria that can be used to judge the operation of a system instead of specific behavior. This section describes the functional and non-functional requirement of the proposed model.

i.. Functional Requirements

Functional requirements are associated with specific functions, tasks or behaviors the system must support. In this section, the main functional requirements required for the proposed model were identified. Table 1 summarizes functional requirements needed for the model.

Table 1: Functional requirements of the model

Functional Requirement	**Issue to be addressed**
The model shall validate the land title information	Changing of land title information without been detected by the users who affected by those changes.
The model shall validate the land title transactions	Changing of transaction information without been detected by the system.
The model shall notarize the land registration process	Manual notarization process consumes a lot of time which lead to delay in issuance of land title
The model shall distribute fingerprint of information stored in ILMIS to several computers using blockchain technology.	Having centralized database leads to single point of failure or attack which leads to loss of important information

ii. Non-Functional Requirements

Non-functional requirements define the overall qualities or attributes of the resulting model. Non-functional requirements place restrictions on the product being developed and specify external constraints that the new system must meet. In this section, the main non-functional requirements for the model were described. The following are non-functional requirements identified for the designed model.

Security

The model handles very sensitive data, so security is very important. The model allows users who are registered with ILMIS only. The information sent to the factom and bitcoin blockchains are just fingerprints of the information stored in ILMIS, so it cannot bring harm even if it falls in wrong arms.

User Interfaces

All user interfaces are in web-based format. They can be accessed easily with standard web browsers and normal mobile devices like smartphones and tablets.

Environment

The client side runs on any environment which supports a web browser. Also, it runs on any android and ios device. The server side environment is not a concern of the client and can be upgraded/ changed without affecting the clients.

Availability

The model gets all of its data from ILMIS database, factom and bitcoin blockchains. The information from blockchain guarantees the availability of 99.9% (Snow, 2015). This is because the same copy of the information is stored in thousands of computers. The information from ILMIS database depends on the availability of ILMIS itself.

B. Design Architecture of the Model

Taking a look at Figure 1, the architecture of the proposed model is seen with integrated components. The components are ILMIS system, factom and bitcoin blockchains, and the model itself. ILMIS systems component is how the model communicates with the ILMIS system. ILMIS receives credentials entered by the user from the model for validation and verification purposes. Moreover, ILMIS receives from the model the information entered by the user about a certain transaction or a land title. ILMIS responds to the request from the model with the status of the user, the information requested by the user about a certain transaction or a land title. Factom and bitcoin blockchains component is used to store the fingerprints information received from the model to the different computers all over the world. However, whenever the fingerprints information is needed by the model, the factom and bitcoin component responds with the same piece of information stored. The model component executes all the commands which requested by the user including encrypting the information from ILMIS database and then compare it with the information stored in blockchains for verification purposes. The model component presents the validation and verification report to the user which also includes performing notarization process for the issuance of land titles and certificates.

C. Model Requirement Analysis

i. Use Case Diagram

Use case diagrams show the interaction between the outside worlds and the model. The diagram describes a sequence of actions or the system behavior that provide something of measurable value to an actor. Also, use case diagrams help to understand system requirements in depth. The use case diagram in Figure 2 shows the interaction between the user, model, ILMIS system, and the blockchains. The user verifies land title information and able to get land titles histories from the model. Bitcoin and factom blockchains receive fingerprints of the land titles information from the model. ILMIS put land title information to the model.

ii. Sequence Diagram

A sequence diagram shows object interactions arranged in time sequence. It depicts the objects and classes involved in the scenario and the sequence of messages exchanged between the objects needed to carry out the functionality of the scenario. Figure 3 shows an example of how the user is interacting with the model. A user starts accessing the model by entering his/her credentials, which are then forwarded to the ILMIS database for verification. ILMIS responds with status on whether user credentials are accepted or not. If the user credentials are accepted, the user will be requested to perform his/her action. The action illustrated in Figure 30 is to verify land title information. The information entered by the user is checked to the ILMIS if the information is not in ILMIS he then prompted the information is not found. If the information is found, the information will then be encrypted and compared with the fingerprints information from blockchains. Lastly, the user has prompted whether the land title information is valid or not.

iii. User Interfaces

The model contains two main functionalities. Firstly, it is to certify land title information. Secondly, it is to verify land title transactions to approve that they are correct and valid. Figure 4 in top panel shows the interface for land title information which allows the user to prove that the information about the certain land title is correct. This interface contains land title id to identify a particular land parcel, fingerprint information of a particular land parcel which used to verify that land title information remains unchanged and the validity checkbox which has a tick for the valid title or unchecked for the non-valid title. Figure 4 in bottom panel shows the interface for transactions involving land titles which allow the users to prove that the transactions are correct and valid. This interface contains transaction id of a particular land parcel, fingerprint information of that transaction which is used to verify that the transaction information remains unchanged, and the validity checkbox which has a tick for the valid transaction or unchecked for the non-valid transaction.

3.3 Testing of the Model

The model was tested for verification using statistical usage model (Markov chain). Markov chain is a widely recognized approach to guarantee the correctness of a system by checking that any of its behaviors is a model for a given property. The statistical usage model is simple to implement, understand and use by all people who are not pure researchers.

Figure 5 shows the process of testing the model using state diagram. It indicates 7 steps which were followed by the model for verifying land title information and transactions. Before the testing process, the study assumes that the records have already been stored in both ILMIS and in factom and bitcoin blockchains. Figure 5 shows the user starts step 1 by putting his credentials, and then is allowed to continue with step 2. In step 2, user credentials are checked in ILMIS database for validation. Wrong user credentials force the user to return to step 1, on other hand right credentials allow the user to continue to step 3.

In step 3 the user searches for land titles information or land titles transactions. If the information searched is not available, the user is prompted to check the spelling correctly and try again. Availability of information means that the system goes to the step 4, to retrieve the information from ILMIS database. In step 5 the model encrypts the information from the ILMIS to get the fingerprints. In step 6 the model searches the fingerprints from the blockchains. In step 7 the model compares encrypted fingerprints obtained in step 5 with the fingerprints from blockchains obtained in step 6. If the encrypted information from step 5 is also found in blockchains from step 6 means that the information is valid, otherwise, means the information is not valid.

The results of the model are summarized in Table 2. The results are divided into seven states. The first state from step 1 to step 2, the transitional stimuli was the user to insert to the model his credentials the probability of success was 1 (100%). The second state from step 2 to step 3, the transitional stimuli was to check for the entered credentials from ILMIS with a probability of success of 0.5 (50%). Another probability of 0.5 was for the wrong credentials entered. The third state from step 3 to step 4, the transitional stimuli was to search for transaction or land title information with a probability of success of 0.5 (50%). The probability of failing may be caused by wrong credentials entered or bad connection. The fourth state from step 4 to step 5, the transitional stimuli was to retrieve the information from ILMIS with a probability of success of 1. The fifth state from step 5 to step 6, the transitional stimuli was to encrypt the information from ILMIS to get the fingerprints with the probability of success of 1. The sixth state from step 6 to step 7, the transitional stimuli was to check for the same fingerprints from the blockchains with a probability of success of 1. Final state from step 7 to the final step, the transitional stimuli was to check for the comparison between the encrypted information from the ILMIS and the fingerprints from the blockchains. The similarities between them mean that the information is valid, otherwise, the information is not valid. The state had the probability of success of 0.5 for valid information and probability of success of 0.5 for non-valid information.

4. Conclusion

Having the system which is able to prevent its data from unauthorized changes it is advantageous to the land administration and title registration process. This system will be able to solve conflicts in the society which are caused by one land plot having more than one owner. The system will be able to prevent corruption because the individuals who were able to make changes without been noticed it will be difficult for them to do that again.

The system which has the capability of providing self-notarization in title registration process has the advantage of eliminating the number of days which were used for notarization in the issuance of land titles. This can eradicate the time of forty days recommended by ILMIS to just a single day (minutes).

This study recommends the following; first, proposed model has to be implemented to the ILMIS infrastructure, because this will increase security whereby land title records will be prevented from both internal and external attacks. The proposed model can also be used in property registration, business registration and any other sort of registration which will require certification.

Second, disintegration in land administration and title registration process make difficult for normal transactions concerning land titles to take a lot of time. Land administration and title registration process should be uniform, this will simplify the process of coding land titles to the system and hence, will simplify transaction process.

Third, regulators such as TCRA and TRA should start immediately to look how they formulate rules and laws concerning the blockchain technology. This technology has led to digital currency and is still going in other socio-economic sectors like agriculture, health, electricity, etc. Without a proper regulation, people can use this technology negatively.

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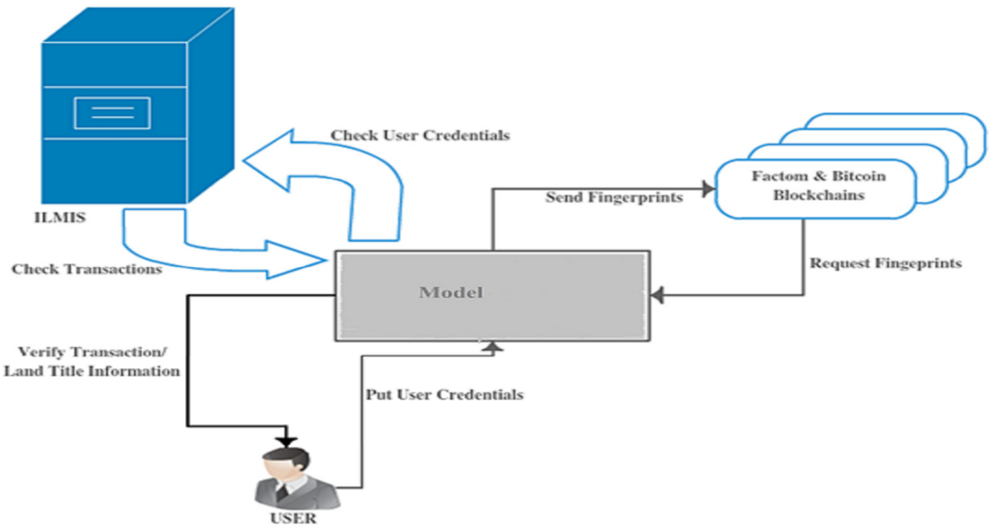

Figure 1: Design architecture of the model for land registration and administration

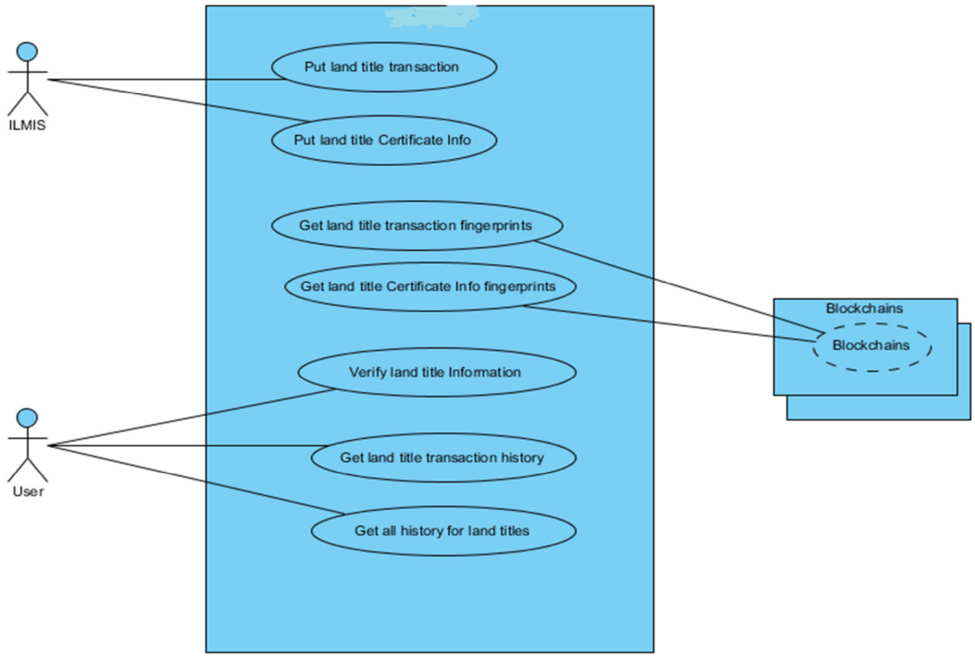

Figure 2: Use case diagram showing interaction in the model

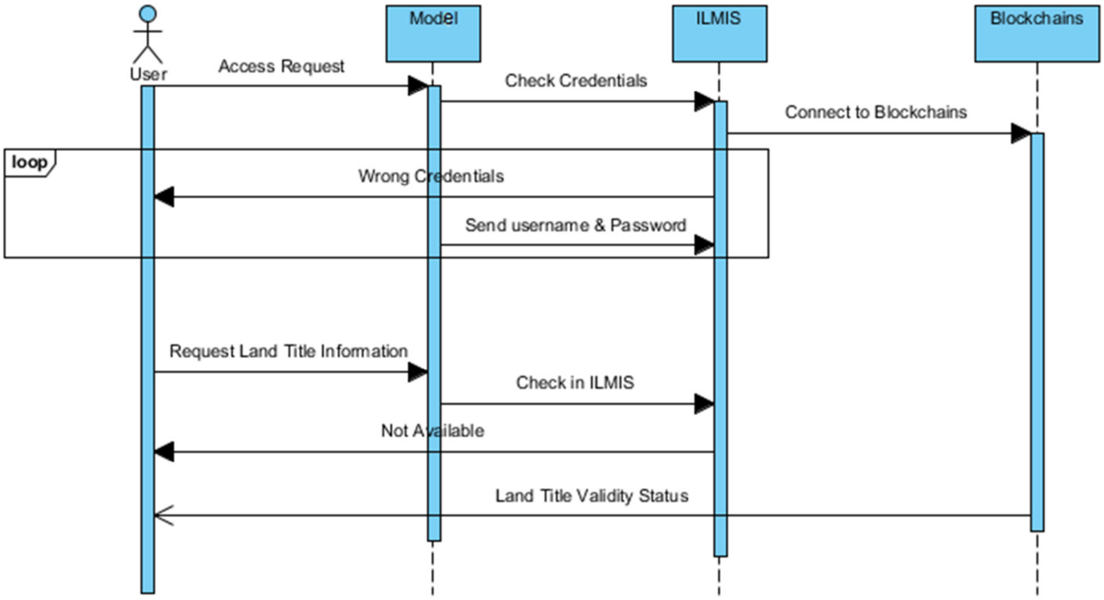

Figure 3: Sequence diagram for the model

Figure 4: User interfaces showing land title information (top panel) and land title transactions (bottom panel)

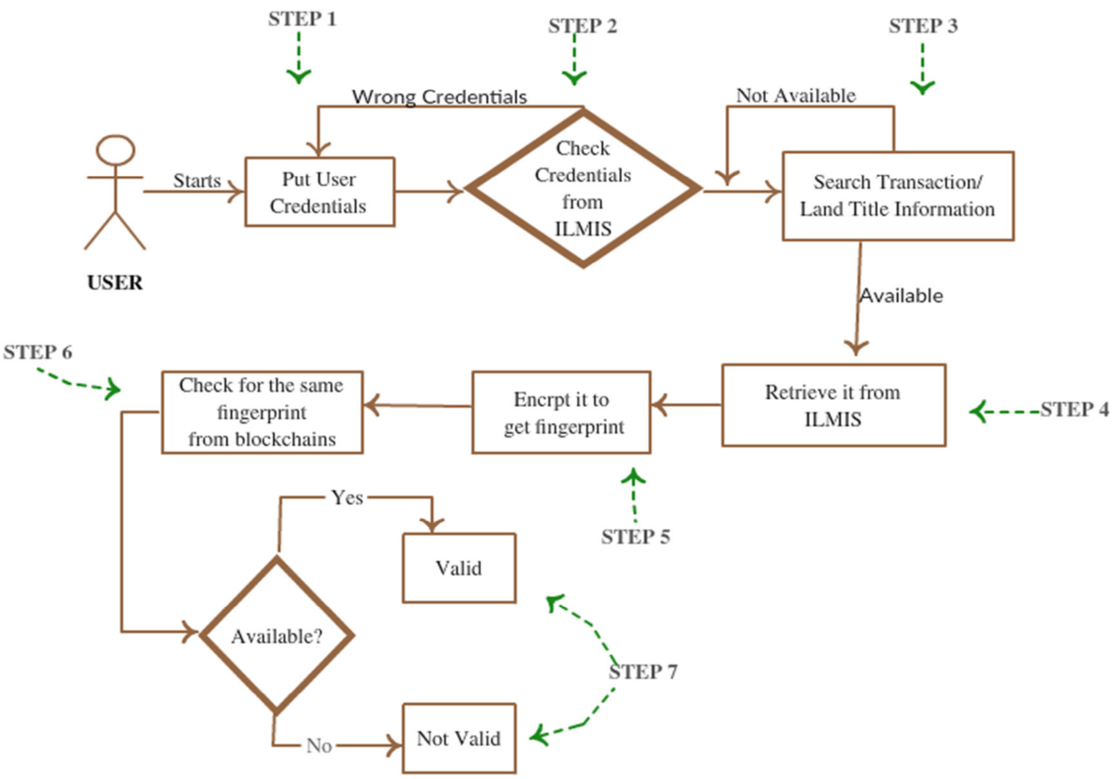

Figure 5: Model testing for verification

Table 2: Testing Results of the Model

State	**Transitional Stimuli**	**Output**	**Probability**	**Expected Percentage**
Step 1 – Step 2	Inserting user credentials	Succeed	1	100%
Step 2 – Step 3	Checking credentials from ILMIS	Wrong credential	$\frac{1}{2}$	50%
		Succeed	$\frac{1}{2}$	50%
Step 3 – Step 4	Searching for transactions or land title information	Available	$\frac{1}{2}$	50%
		Not Available	$\frac{1}{2}$	50%
Step 4 – Step 5	Retrieving information from ILMIS	Succeed	1	100%
Step 5 – Step 6	Encrypting information from ILMIS to get fingerprint	Succeed	1	100%
Step 6 – Step 7	Checking for the same fingerprint from blockchains	Succeed	1	100%
Step 7 – Final	Checking for the validity of the information	Not Valid	$\frac{1}{2}$	50%
		Valid	$\frac{1}{2}$	50%