Developing Blockchain-Powered E-Government Service to Create Transparency in Land Title Registration, the case of Ethiopia

Belay Zeleke
HiLCoE, Software Engineering Programme, Ethiopia
belayomo.it@gmail.com

Mulugeta Libsie
HiLCoE, Ethiopia
Department of Computer Science, Addis Ababa University, Ethiopia
mlibsie@yahoo.com

Abstract

Land is a significant resource for growth and development. The land sector is particularly susceptible to corruption and rent seeking globally. There is a high risk of corruption in Ethiopia's land administration service. Proper administration of land is critical for the future growth and development of the country. Applying information technology in the land administration service can increase the quality of service provision. A blockchain is a transparent distributed database that records details on all transactions. Once data is registered on a blockchain, it is secure and unalterable and provides a permanent record. Because of the distributed ledger nature of blockchain technology, it can increase the availability and security of a system.

This paper examines the potential impact of implementing blockchain technology on the land administration service and how it can help in creating transparency in land administration service and fighting corruption in the land sector. We implemented blockchain technology for the proposed model using hyperledger fabric and hyperledger composer fretwork. It is believed that the work contributes to an improved knowledge about blockchain technology and its potential benefits and challenges in the implementation of e-government services. We concluded from the study that blockchain powered Land Information System is the ultimate solution to create transparency, eradicate corruption, and create trust in the land administration service.

Keywords: Blockchain; E-government; Hyperledger Fabric; Hyperledger Composer; Land Information System

1. Introduction

Land is a key resource for growth and development. Access to rural land holds the promise to reduce poverty and foster sustainable development. At the same time, in the context of rapidly growing urban populations such as Ethiopia's capital, Addis Ababa, one of the fastest growing urban areas in the world, urban land and access to adequate housing becomes a highly sought after commodity. In Ethiopia, access to land is extremely important and has become a major socio-economic asset [3]. Implementing e-government in the land administration system can improve service delivery. Adopting blockchain technology for Land Information System (LIS) will increase transparency on land administration services.

The land sector is particularly susceptible to corruption and rent seeking globally. The value of land thus creates a significant opportunity for corruption on the part of those with the legal authority to assign, revoke, or restrict rights to it [1]. There is a high risk of corruption in Ethiopia's land administration. According to [2], half of all companies expect to give gifts when applying for a construction permit and paid a bribe to land administration officials. Petty corruption, tampering land owner title, and land-grabbing are common in the land administration sector. This is caused by the absence of strong institutions, transparency, clear policies, and land title registration software. This research raises the following main questions to address the problem.

1) How can blockchain technology be used to create transparency on land administration service?
2) What type of blockchain technology is appropriate for land administration service?

The general objective of this paper is to identify and develop blockchain powered e-government model for Ethiopian Land Administration service to create transparency and fight corruption.

One of the important things to fight corruption in the land administration service is transparency. Transparency refers to the availability of information to the general public and clarity about government rules, regulations, and decisions. Transparent procedures include open meetings, financial disclosure statements, freedom of information legislation, budgetary review, and audits. Transparency in government serves as a deterrent to corruption can inspire trust in the governance process. To establish trust in the government, transparent governance ensures that money is spent for the intended purpose. The government should avail the necessary information on the government's official website to create transparency [9].

Traditional database applications are based on client-server architecture. Clients are end-users of the application that request a particular service [10]. Traditional database applications have an advantage over blockchain technology in scalability, easy maintenance, and high throughput. Traditional database applications have their own limitations compared to blockchain technology. They have limitations on identifying data inconsistencies and correcting any unreliable information, robustness, security, and anybody with sufficient access to a centralized database can destroy or corrupt the data within it [10].

Blockchain is a transparent distributed database that records details of all transactions performed by the system's participant agencies. It is a decentralized public ledger that allows all participants to keep track of and verify transactions without the need for a central party [4]. Once data is registered on a blockchain, it is secure and unalterable and provides a permanent record. Blockchain provides the ultimate solution in transparency and trust, making this technology an exciting prospect for organizations that strive to conduct transparent business [13].

There are three general high-level categories for blockchain approaches: Permissionless, Private Permissioned, and Public Permissioned (Federated Blockchains or Consortium Blockchains). A consensus algorithm can be defined as the mechanism through which a blockchain network reaches an agreement. There are several consensus algorithms. The most popular are Proof-of-Work, Proof-of-Stake, Round Robin, Proof-of-Authority/ Proof-of-Identity, and Proof-of-Elapsed Time.

The blockchain platform or frameworks are software solutions that simplify the development, deployment, and support of technically complex products. Building a blockchain application from scratch can be quite complicated. However, blockchain platforms allow to develop blockchain applications with ease. Since there are a variety of blockchain platforms, we need to pick the one that meets business requirements. Here it is important to mention the different types of Blockchain platforms that can be used by enterprises. Some popular paltforms are Hyperledger Fabric, Hyperledger Sawtooth Lake, IBM Blockchain, R3 Corda, BigChainDB, and Open-chain.

Blockchain technology has a benefit in reducing transaction cost, achieving data security, creating trust in the government, creating transparency, and streamlining business processes across multiple entities (reconciliation). We believe that it is important to understand the limitations of blockchain technology and the different trade-offs that result from different choices in architecture and design. Without a clear understanding of these trade-offs, it is impossible to know where blockchain technology can be best applied, let alone whether it should be considered at all [12]. Before deciding to implement blockchain technology, one should consider the following points: Blockchain technology is not the best solution for every problem; the adoption of blockchain technology should consider infrastructure development (ICT, Electric grid, etc.); and human capacities [8]. Hence, selecting appropriate blockchain type, selecting the right consensus algorithm, and selecting the right blockchain platform are important.

2. Related Work

The work by Lazuashvili [6] is intended to evaluate Georgian land title blockchain project. The following strong factors are identified for the successful adoption of blockchain technology in the Georgian land title registration system: existing e-Government, Public-Private Partnerships, Legislative

framework, and Research and Development activities. The weakest points in the blockchain project of Georgian land title are that no specific research projects had been done before launching the pilot project in 2016 and no specific metrics were identified for the evaluation of the results of the project. The blockchain solution is not integrated into the land titling service itself, but an add-on service on the existing land title process. The issues in the current public service provision processes are identified that blockchain technology helps to reduce corruption, reducing the red tape, improving the speed of transactions, increasing data security, offering more transparent state-citizen relationships and creation of better tools of data traceability.

The purpose of the research by Corluka and Lindh [7] is to examine the implications of the implementation of blockchain technology within the real estate sector and its possible consequences. The positive impacts after implementation of blockchain are less market inefficiey, safety, more stable market, easier to trust the system, and higher transaction frequency. The negative impacts after implementation of blockchain are oligopoly, changes in work tasks, less human contact, less arbitrage opportunities, and problems with adjustments to the increased requirements. The authors draw a final conclusion that blockchain is a promising technology with great ability to fundamentally change not only the real estate market but the market overall.

The objective of the research by Oberdorf [11] is to explore the potential impact of the application of Blockchain technology in land administration and property management. The research analyzed two Ghanaian enterprises that are independently developing digital land administration platforms using Blockchain technology. The author identified the following potential impacts of blockchain platform: it has a positive impact on the perceptions of tenure security; it increases levels of transparency in land transactions; it prevents disputes; it enables access to formal credit from banks, insurances and other financial services; and it enables an active land market for buying, selling and finding investment.

One of the biggest challenges that grip various states in India is the issue of land ownership, which is partly due to the fact that there is no end-to-end effective land records management system. The issue of land ownership is so critical that almost all financial institutions heavily depend on the ownership of land-based properties for collateral security. The objective of the research by Abhishek [14] is to identify problems in the current land management system. It is also intended to evaluate the performance of blockchain-based implementation of land registration system and evaluate whether integrating blockchain technology to the current business process of land record management is a viable solution or not. Factors such as integrity of data, trust in cross-organizational work, and public verifiability are identified as reasons for the current system's problems. The author argues that to solve the current system's problems, blockchain is the best solution because using blockchain technology public verifiability can be easily provided using the cryptographic hash properties of the transactions and the hash linkage of the blocks can be used to provide the traceability of a particular record. Private and permissioned blockchains technology is a suitable cross-organizational workflow to create trust between departments. Also, the distributed architecture of the blockchains helps in preventing unauthorized modification of data via consensus mechanisms.

3. The Proposed Solution

Registering land properties and availing land information for different stakeholders have many benefits. Information technology can play a great role in the land administration process. Selecting the right technology for the land title registration system can help in creating transparency in the land administration process, track changes made on land title, and providing better service for the society. The proposed solution in this paper aims to create transparency by integrating blockchain technology in the land administration service. There are different blockchain technologies available for different industries. We choose hyperledger fabric blockchain with hyperledger composer framework for land administration service because of the following reasons [5].

- The technology has the capability to track the origin of every transaction inside the blockchain ledger,
- Security,
- Support for the participation of multiple organizations,
- The simplicity of the technology,
- API support,
- Low implementation and running cost,
- Participants identification,
- High transaction throughput performance, and
- Low latency of transaction confirmation.

Hyperledger composer is a framework to accelerate the development of applications built on top of Blockchain platforms such as hyperledger fabric. Hyperledger Composer is used to model business network quickly, containing existing assets and the transactions related to them. Assets are tangible or intangible goods, services, or property. As part of our business network model, we define the transactions which can interact with assets. Business networks also include the participants who interact with them, each of which can be associated with a unique identity, and across multiple business networks. Hyperledger composer uses model file, scrip file, Access Control file and Query file to build blockchain application. The model file is used to model asset, participant, transaction, and event. The script file is used to implement transactions, in our case it is used to transfer landowner title. The access control file is used to define access control rules. Access control rules allow fine-grained control over what participants have access to what assets in the business network and under what conditions [5].

The proposed architecture has three layers: client layer, middle (hyperledger composer) layer, and Blockchain Layer (Hyperledger fabric).

The *client layer* requests service from blockchain network through the middle layer (hyperledger composer). The client layer can be an existing legacy system or external third party application or playground.

The *middle layer* (Hyperledger Composer) contains API, Hyperledger composer REST server, and SDK. API is used to integrate with existing land information systems and requests service from the blockchain network. Integrating existing land information systems allows to pull data from land information systems and convert them to assets or participants in a Composer business network. The REST Server will generate a set of REST APIs from a LIS Model. REST API can then be called from a LIS to interact with a Blockchain. When the LIS calls one of the REST APIs, the REST server will then submit a transaction to the hyperledger fabric blockchain. The SDK provides APIs for transaction processing, event handling, node traversal, and membership services. Land information system can communicate with hyperledger fabric network using REST API. REST API communicates with hyperledger composer REST server and REST server communicates with hyperledger fabric network. Using Playground locally, we can connect to a Web Browser which works in the browser's local storage, or we can use Connections to a real fabric usually in a group.

The *third layer* is hyperledger fabric. It contains CA (Certificate Authority), channels, peers, and chaincode. Each organization has a CA to authenticate blockchain network users. The channels are used to ensure private and confidential communication between privileged organizations' nodes. Channels help to partition the fabric exchange confidential private transactions with the isolation of traffic between municipalities (members) and establish data privacy by separating ledgers per channel. We can also create transparency on the land administration service by creating channels and expose land information to the public or stakeholders or the society for auditing the land information that can help to create transparency and eradicate corruption on land administration. We can anchor peer nodes on a channel that all other peers can discover and communicate with. Each member (organization) on a channel has at least one anchor peer (on the proposed architecture we recommend at least two anchor peers to prevent a single point of failure), allowing peers belonging to different organizations to discover all existing peers on a channel. A peer receives ordered state updates in the form of blocks from the ordering service and

maintains the state and the ledger. Peers can additionally take up a special role as an endorsing peer, or an endorser. The orderer node is responsible for packaging transactions into blocks and distributing them to anchor peers across the network. Multiple organizations can join the hyperledger fabric network but for the purpose of demonstration, we are showing only two organizations in the architecture shown in Figure 1.

In the proposed system, persistent data is stored in non-volatile storage such as hard disk. LIS uses a distributed blockchain ledger to store persistent data. The ledger component at each peer maintains the ledger and the state on persistent storage and enables simulation, validation, and ledger-update phases. Broadly, it consists of a block store and a Peer Transaction Manager (PTM). The ledger block store persists transaction blocks and is implemented as a set of append-only files. Since the blocks are immutable and arrive in a definite order, an append-only structure gives maximum performance. In addition, the block store maintains a few indexes for random access to a block or to a transaction in a block. The PTM maintains the latest state in a versioned key-value store. It stores one tuple of the form (key, val, ver) for each unique entry *key* stored by any chaincode, containing its most recently stored value *val* and its latest version *ver*. The version consists of the block sequence number and the sequence number of the transaction (that stores the entry) within the block. This makes the version unique and monotonically increasing.

The PTM uses a local key-value store to realize its versioned variant, with implementations using LevelDB and Apache CouchDB. PTM provides a stable snapshot of the latest state to the transaction. The ledger component tolerates a crash of the peer during the ledger update as follows. After receiving a new block, the PTM has already performed validation and marked transactions as valid or invalid within the block. The ledger now writes the block to the ledger block store, flushes it to disk, and subsequently updates the block store index. Then the PTM applies the state changes from write all valid transactions to the local versioned store. Finally, it computes and persists a value savepoint, which denotes the largest successfully applied block number. The value savepoint is used to recover the indexes and the latest state from the persisted blocks when recovering from a crash.

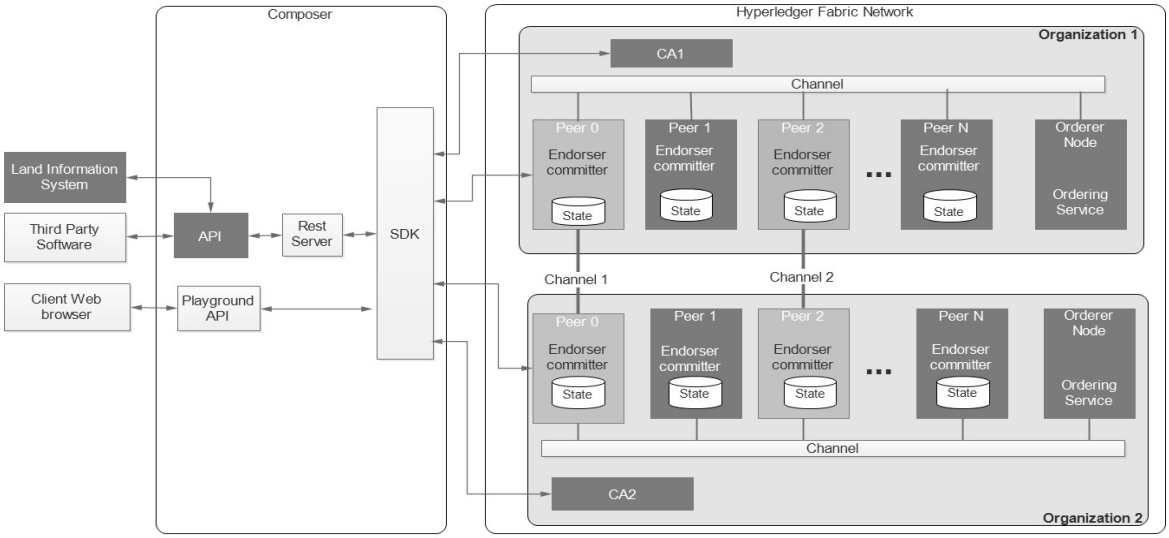

Figure 1: Hyperledger Composer Base System Deployment Architecture

For the production environment disaster recovery is recommended, persistence is part of a high availability suite which provides replication and instant failover. In all cases, to protect against data corruption, it is recommended to take regular backup of the storage associated with every deployed component. Because the ledger is shared across all the peers and ordering nodes, taking regular backups is critical. For example, if incorrect data is accidentally propagated to a peer's ledger or if data is

mistakenly deleted, the incorrect data might spread to the ledgers of some other peers. This would require the restoration of the ledgers of all the peers from an established backup point to ensure synchronicity. We can decide how often to perform the backups based on our recovery needs, but a general guideline would be to take daily backups.

4. Implementation

Implementation of the land registry system did not include all functionalities identified. For the purpose of demonstration, we considered only the basic functionalities. For the development of blockchain-based LIS, we used hyperledger fabric, hyperledger composer, and hyperledger composer playground as development tools. To run Hyperledger Composer and Hyperledger Fabric on a virtual box machine, it is recommended to have at least 20 GB of hard disk space and 2 GB RAM on the host machine. The following should be installed: Docker Engine, Docker-Compose, Node, npm, git, and Python. The following tools should be installed for development, testing, and run the application: Command Line Interface, Generator Hyperledger composer, Yeoman code generator, Playground Web User Interface, and Hyperledger Fabric. We can control our runtime using a set of scripts which can be found in the development folder *~/fabric-dev-servers*. The first time we start a new runtime, we need to run the start script, then generate a PeerAdmin card using the *./createPeerAdminCard.sh* script. We can start and stop our network runtime using *~/fabric-dev-servers/stopFabric.sh*, and start it again with *~/fabric-dev-servers/startFabric.sh*.

a. Creating Business Network, Defining Asset, Participant, Transaction and Access Control

We will walk through setting up a LIS blockchain network, defining our assets, participants, and transactions, and testing our network by creating some participants and an asset, and submitting transactions to change the ownership of the land title from one landowner to the other.

Creating a New Business Network (LIS Blockchain Network): To create a new business network from scratch we set basic information of LIS blockchain such as network name, description, and network Admin card. After providing all requirements, we can deploy the LIS blockchain network. Now that we have created and deployed the LIS blockchain network, we can see a new LIS blockchain network card called *admin* for our LIS blockchain network *blockchain-land-info* in the wallet. LIS blockchain network cards (wallets) combine a connection profile, identity, and certificates to allow a connection to a LIS blockchain network in Hyperledger Composer Playground. The wallet can contain LIS blockchain network cards to connect to multiple deployed LIS blockchain networks. Playground allows us to create and edit model, script, access, and query files that are used to define LIS blockchain networks. We have two model files. The first one is base model file, and the second one is land model file. Base model file is used to model concept, enumerated types (enum is predefined data type) and abstract participant. Land model file is used to define the assets, participants, transactions, and events in our LIS blockchain network.

Define Participant: Participants are members of the LIS blockchain network. To capture participant information on the LIS blockchain network, we should define first on the model file. A model file like a database in traditional applications is used to define data filed on the blockchain network. In the LIS blockchain network, there are six participants, two assets and one transaction. The common data fields are defined in the concept, abstract participant and enumerator in the model file. Assets are the resources which our business model has. Land and certificates are assets in our model. Creation, deletion, and update assets are supported by default by Composer. The way that the participants interact with the network and with the assets is through transactions which are the chaincode functions with certain parameters invoked by a user of the network. Any transaction invocation is always recorded in an immutable historical record. All the creation, deletion and update transactions are already supported by default by Composer, but all other behaviors need to be modeled, and sometimes, even these default transactions should be made restricted and replaced by custom made ones, to ensure system integrity.

Transaction: Now that the domain model has been defined, we can define the transaction logic for the LIS blockchain network. Composer expresses the logic for a LIS blockchain network using JavaScript functions. These functions are automatically executed when a transaction is submitted for processing. We created a script file and write chainofcode (smart contract) to perform a transaction (transferring land title from one land owner to a third person).

Access Control: Access control file is used to define access control rules for the LIS blockchain networks. Our network is simple, so the default access control file does need editing to add a participant's role. The basic file gives the current participant admin (NetworkAdmin) full access to the LIS blockchain network and system-level operations. Based on LIS access control rule we can modify access control file to restrict the role of the participant in the LIS blockchain network.

Now that we have models, script, and access control files, we need to deploy and test our LIS blockchain network. Hyperledger composer playground has a feature to deploy business network.

b. Testing LIS Blockchain Network

We need to test our LIS network by creating some participants (in this case *land Owner*, *Land Owner Family*, and *Land Administrator*), creating an asset (Land), and then using Land title transfer transaction to change the ownership of the land

Create Participant (Landowner): We open Landowner from Participant Menu from the composer playground, check the optional checkbox to insert optional properties of a landowner, and insert land owner detail information. Then the system automatically evaluates and adds landowner information to the LIS blockchain network. After creating landowner on the network we can update, delete and view landowner information in the same way we can create, update and delete Land Administrator, Land Registrar, System User, and landowner family.

Creating Asset (Land title): Another integral component of the system is the assets for the asset management aspect of land registration. If traceability of the land is to be achieved, these products need to be modeled as assets, so that the network can register which ones exist, their status, and any changes that happen. We can create new land information on the LIS blockchain network by opening Land registration page from Asset Menu from the home page of playground. To insert optional properties of Land we check on the optional properties checkbox and insert land detail information as shown in Figure 2. The peer node evaluates and adds to the LIS blockchain network. We can also update and delete land information after land information is created on the LIS blockchain network.

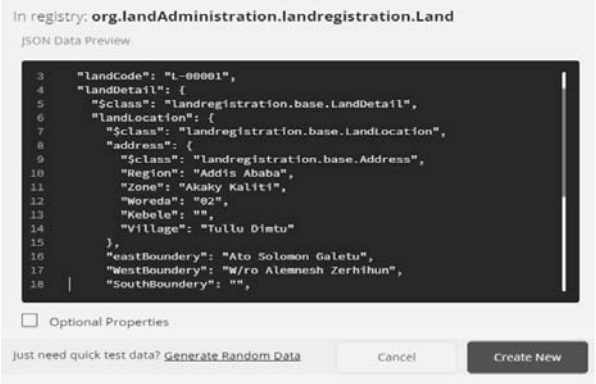

Figure 2: Creating New Asset

Transaction (Transfer Land Title): The historian is a specialized registry which records successful transactions, including the participants and identities that submitted them. The historian stores transactions as Historian Record assets, which are defined in the Hyperledger Composer system namespace. To transfer Land title, we open a transaction page and select transaction type "LandTransfer". Insert Landcode and new owners ID and submit the transaction, then the system automatically evaluates and changes the owner of land title. Once a transaction is created on the LIS blockchain network, the transaction history will not be removed from the ledger. This feature helps in the creation of transparency and helps to track transaction history. We can view transaction history by clicking on the *All Transaction* button under the transaction submenu and the transaction list will be displayed on the page. It contains Data Time, Entry Type, and Participant columns. We can also view transaction detail of each record.

5. Conclusion and Future Work

The land sector is particularly susceptible to corruption and rent seeking globally. The value of land thus creates a significant opportunity for corruption on the part of those with the legal authority to assign, revoke, or restrict rights to it [1]. There is a high risk of corruption in Ethiopia's land administration. One of the important things to fight corruption in the land administration service is transparency. Transparency in government serves as a deterrent to corruption and can inspire trust in the governance process. Blockchain is a transparent distributed database that records details of all transactions performed by the system's participant agencies. It is a decentralized public ledger that allows all participants to keep track of and verify transactions without the need for a central party. Blockchain technology has a benefit in reducing transaction cost, achieving data security, creating trust in the government, creating transparency, and streamlining business processes across multiple entities (reconciliation).

This paper examined the potential impact of implementing blockchain technology on land administration service and how it can help in creating transparency and fight corruption in the sector. We developed blockchain-powered Land Information System using hyperledger composer playground to simulate blockchain technology.

Future work will be further study on blockchain technology, develop mobile and web applications and integrate them with the blockchain application.

References

[1] J. Plummer, "Diagnosing Corruption in Ethiopia", World Bank, 2012.

[2] "Ethiopia corruption report", August 2017, https://www.business-anti-corruption.com/country-profiles/ethiopia/, Last accessed on Feb 6, 2019.

[3] S. Lindner, Transparency International, "Overview of corruption in land administration", U4 Expert Answer, 2014, pp. 1-9.

[4] Jefrey Dinham, "A practical guide to how blockchain could end corruption in South Africa", Feb 16, 2019, https://qz.com/africa/1238247/corruption-in-south-africa-blockchains-open-ledger-could-bring-transparency

[5] "Hyperledger composer", retrieved from https://hyperledger.github.io/composer/latest/, Last accessed on November 12, 2019.

[6] N. Lazuashvili, "Integration of the Blockchain technology into the land registration system.A case study of Georgia", Master's thesis, Tallinn University of Technology, 2019.

[7] D. Corluka and U. Lindh, "Blockchain A new technology that will transform the real estate market", Master's thesis, Royal Institute of Technology, Stockholm, Sweden, 2017.

[8] R. Zambrano "Unpacking the disruptive potential of blockchain technology for human development", International Development Research Centre, Ottawa, Canada, August 2017, https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/56662/IDL-56662.pdf

[9] "What is Transparent Governance?", https://market-research-tools.knoji.com/what-is-transparent-governance/, Last accessed on June 21, 2019.

[10] Shaan Ray, "Blockchains versus Traditional Databases", https://towardsdatascience.com/blockchains-versus-traditional-databases-e496d8584dc, Last accessed on Nov. 23, 2020.

[11] V. Oberdorf, "Building Blocks for land administration, The potential impact of Blockchain-based land administration platforms in Ghana", July 2017.

[12] G. Hileman and M. Rauchs, "Global blockchain benchmarking study", Cambridge Center for Alternative Finance, University of Cambridge, 2017.

[13] CMS Media, "Canada using blockchain for transparent administration of Government contracts", https://www.cms-connected.com/News-Archive/August-2018/Canada-Using-Blockchain-for-Transparency-of-Government-Contracts, Last accessed on Jan 29, 2019.

[14] G. Abhishek, "Property Registration and Land Record Management via Blockchains", Master's Thesis, Indian Institute of Technology, Kanpur, June 2019.