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A Blockchain-based Land Title Management System for Bangladesh

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ABSTRACT

Bangladesh is a small country with a large population. Its increasingly developing economy further makes land a lucrative source of fixed capital. On the other hand, land titling is a cumbersome and lengthy process, where different government bodies process different sets of documents, and bureaucratic loopholes encourage fraudulent activities by organized people. As a result, the current model suffers from good governance. In this paper, we propose a Blockchain-based solution that offers data synchronization and transparency, ease of access, immutable records management, a faster and cheaper solution. Considering the technological knowledge and capacity of the people and the government, we introduced a phase by phase Blockchain adoption model that starts with a public Blockchain ledger and later gradually incorporates two levels of Hybrid Blockchain. We provide detailed smart contracts design of the public Blockchain and implement a prototype system using Ethereum. Our experimental setup uses local and live Ethereum test networks to demonstrate the efficacy of the proposed system. Our analysis shows that the proposed model reduces the number of required travels, the overall cost of information processing as well as provide easy access to vital information. As a result, Blockchain adoption can improve the land title digitization effort of Bangladesh.

1. Introduction

Bangladesh has a robustly growing economy that is investing heavily towards the vision of digitization by 2021 (Bank, 2019). Though it has a landmass of around 1,47,570 square kilometers, it has to manage a large population of 164 million people (Worldometer, 2020). Furthermore, the ongoing economic development is pushing the conversion of agricultural lands towards lucrative non-agricultural lands. Land is considered as a great source of capital that ensures enhanced livelihood as well as investment opportunities. As a result, ownership of any land piece is heavily contested. Moreover, Bangladesh follows a century-old model to manage land-related records that started in the era of British India, later continued throughout the Pakistan period, and still practiced even after the formation of the new republic. In this current model, ownership of a piece of land is ensured by various types of physical documents such as Deed, Parcha, Registration, Mutation, etc. that are managed by different branches of the government. To make things worse, bribery is abundant among the land record management officials, law enforcement individuals, and even inside the judiciary process (Rahman and Hossain, 2020).

Various loopholes in the current procedures are exploited by the land sharks in collusion with the authorities of position and power to falsify documents and later claim false ownership or forceful land grabbing that finally leads to the highest number of civil disputes in the judiciary system. Many of these cases take months or years even decades to get resolved through the journey from local courts to the supreme court. The amount of time and money that gets wasted in the process is unbearable for the common man of the country (Khan et al., 2009; Rahman and Hossain, 2020). Though the government has started the procedure of record of rights (ROR) digitization, it is still in the phase of development and their use case is limited to archival activities only. Bangladesh is divided into 8 divisions (Bibhag), 64 districts (Zila), and each Zila is further divided into Upazilas. The government initiated an E-Mutation system as a pilot program on some Upazilas but it is just an online application system yet to be integrated with different branches that can provide real benefit to the common people of the country (Saif and Hawlader, 2019). So, it is very important to find a sophisticated mechanism that can be easily integrated with the ongoing digitization efforts as well as can incorporate current land related transactions (e.g. transfer, purchase, sale, gift, mortgage, inheritance and partition deeds) with higher level of integrity and authenticity.

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1319-1578/

The key problem with the current system is that information is fragmented in multiple government offices that are not synchronized very well and corrupted people can conspire to modify legal documents. In this case, a centralized system will not be sufficient to handle various frauds related to land titling (Rabbani, 2020). Distributed ledger technology (DLT) such as Blockchain can provide some important solutions to this problem. DLT is a database model, where several nodes are connected in a peer-to-peer network, and each node stores the complete copy of the ledger. Any modification to the ledger is agreed upon by the majority (e.g. Proof-of-Work, Proof-of-Stake) of the connected nodes, which makes it extremely difficult to falsify by any single node or group of nodes (Suciu et al., 2018).

The inherent nature of a land title is attached to its earlier history of ownership and how it has been changed over time. This chain of documents preserves the integrity of land ownership, which matches the fundamental building block of Blockchain. In the case of Blockchain, every newly added block maintains a chain with its previous block and it can be traced back to the root node (Narayanan et al., 2016). This property can be applied to the land ownership transfer scenario. On the other hand, once a new block is accepted by the peer-to-peer Blockchain community, it is very difficult to change the previous blocks that again make it immutable. This property of Blockchain is further useful to handle the document falsification possibilities by people of authority. Also, every node present in the Blockchain network maintains a complete copy of the full ledger which ensures transparency (Ahram et al., 2017). The application of other DLT technologies such as Tangle and Hashgraph is still not proven in this domain (Suciu et al., 2018) whereas Blockchain has already been proposed in similar applications (Thakur et al., 2019; Shang and Price, 2019). As every country has its own cultural and historical model of land title management, it is important to find an appropriate solution for the land ROR maintenance of Bangladesh using modern technology such as Blockchain.

Blockchain is changing the technology landscape since its inception by Satoshi Nakamoto in 2008 (History/of/bitcoin/-wikipedia, 2018). Though early version (i.e. Blockchain 1.0) of its applications was limited to cryptocurrencies such as Bitcoin but further upgraded versions of Blockchain, 2.0, 3.0, and 4.0 have shown tremendous opportunities in the last decade. In these new models, smart contract plays a pivotal role, which is a small script that ensures data related policies are verified before a successful mining operation (i.e. new block creation) is conducted in the Blockchain ledger (White paper ethereum/wiki wiki github, 2018). As there are millions of smart contracts that are deployed in the public Blockchain ecosystems, it is important to focus on the security vulnerabilities of smart contracts (Almadhoun et al., 2018). Also the growing adoption of 5G technologies open the possibilities of increased IoT and AI incorporation in the Blockchain domain (Salah et al., 2019; Chaer et al., 2019). Smart contracts in the age of 5G, IoT and AI can be further helpful to improve the land titling model of Bangladesh.

Currently, Bangladesh uses a paper-based traditional and cumbersome land management policy, where different departments struggle to synchronize their documents which results in versatile types of frauds. Also, the system takes a couple of months to complete the ROR transfer. Court cases or bank lease is also difficult to identify while registering an ownership handover. In order to solve these problems, we propose to incorporate Blockchain that ensures transparency, immutable record management, easier synchronization, and wider accessibility as an inherent property. The main contributions of this paper are the following:

- Describe the existing land titling system with current progress and problems.
- Considering the current pace of land records digitization, technological knowledge of general people, the capacity of government or necessary training of officials, required policies, and laws, we propose a phase by phase Blockchain adoption architecture for Bangladesh land title management.
- In our proposed model, the first phase is a public Blockchain, where regular capable people are miners but the process is governed by the authority. The second phase is a small scale Hybrid Blockchain where the private ledger is managed by public and private trusted institutes and key details are shared with the public ledger. PKI is initiated in the second phase of the development. The final stage is the Full Hybrid Blockchain implementation when the government is ready to increase the scale of the system.
- We have designed and developed smart contracts for the public Blockchain of the land titling system.
- We have implemented a prototype system using the Ethereum Blockchain. Our experimental results demonstrate that the proposed system reduces the number of required travels whereas improves data accessibility, cost of operations, and reliability over the current model.

The rest of the paper is organized as Section 2 describes the existing land management system and digitization efforts of Bangladesh. Section 3 presents state-of-the-art works on the related topic. Section 4 describes the phase by phase Blockchain adoption model. Section 5 details smart contract models for the proposed public Blockchain. Section 6 describes the public Blockchain implementation process using Ethereum. Section 7 details the experimental setup, results, and discuss the necessary measures. Finally, in Section 8 we concluded the paper with possible future directions.

2. Existing land title management system of Bangladesh

Any person who has the right to own an immovable property can be an owner of a piece of land in Bangladesh. The ownership is stored in the record of rights (ROR) or other public documents that are maintained by different bodies of the government. Land record management is a critical part of the land administration, which includes preparation of ROR through survey, mapping of land plots, registration of deeds during rights transfer, and maintenance of various types of land-related documents. Ministries of government that are involved in land administration and management are the Ministry of Land (MoL), Ministry of Law, Justice and Parliamentary Affairs (MLJPA), and Ministry of Establishment (MoE). ROR is prepared by the Directorate of Land Record and Survey (DLRS) under MoL. Deed based right transfer is managed by MLJPA and modification of ROR (i.e. Mutation) is conducted by Upazila administration under the jurisdiction of MoE (Ministry of land, 2020).

General people of Bangladesh are unaware of the complicated procedures of ROR transfer that involves dozens of documents managed by different government offices and a long time period to finalize the process. As a result, middlemen arrives in every scope of administrative and legal loopholes and apply bribery to falsify documents to harass common people. This in turn causes legal tangling for years and is the main source (around 80%) of civil disputes in Bangladesh (Rahman and Hossain, 2020). The complete process of land titling can be divided into 4 stages: original document verification, deal by buyer and seller, payment completion, registration process. Fig. 1 describes the workflow of the existing land ROR transfer process. ROR can be transferred through donation or inheritance as well. Since purchasing procedure creates more difficulty, we base our discussions on this model.

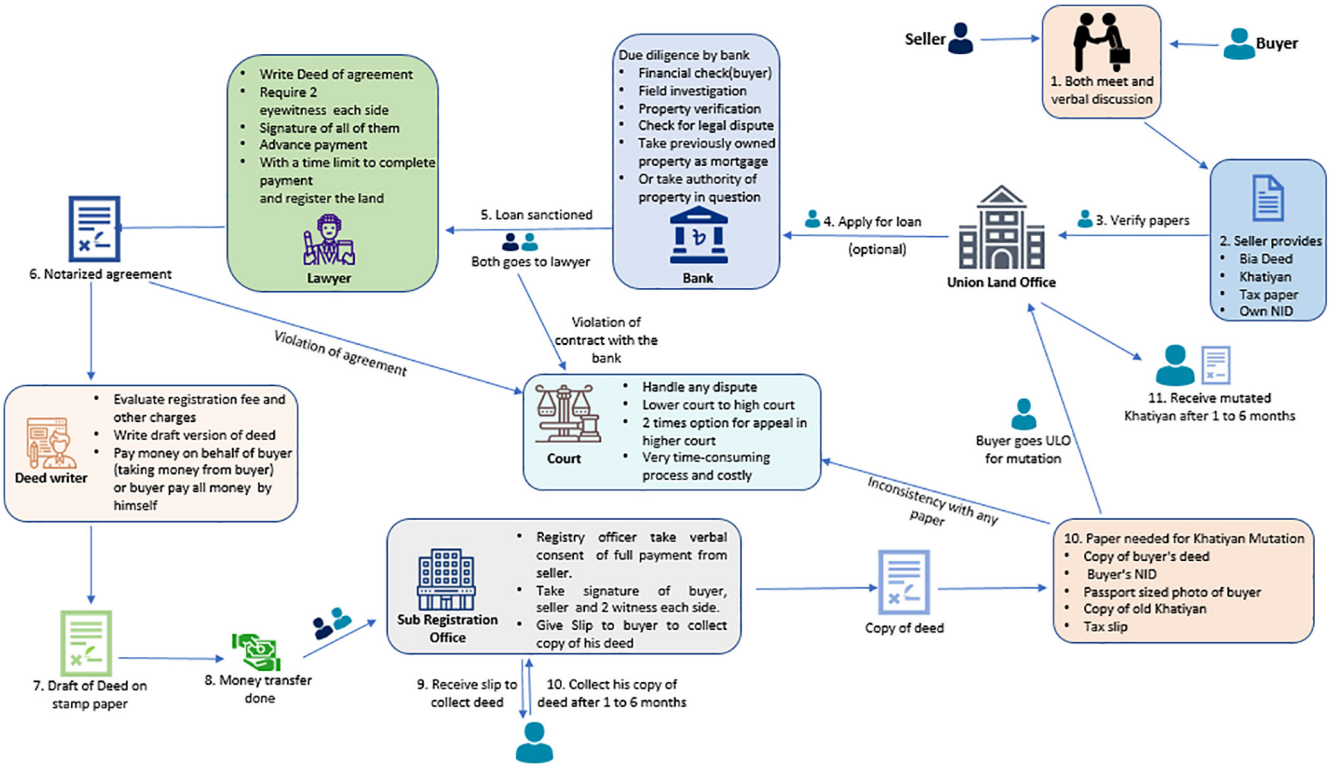


Fig. 1. Existing land title management system of Bangladesh.

2.1. Buyer and seller deal

The first step is to initiate a deal between the buyer(s) and the seller(s). In this step, price and other relevant agreements are made. The seller should provide original documents to the buyer for the verification process. The buyer communicates the land office and other government offices that manage different government records related to the piece of land.

2.2. Document verification

For the land record verification process, it requires to check various government documents along with court cases to ensure fairness. The most notable documents are Bia Deed, Khatiyan records, Mutation document, Non-encumbrance certificate, etc. Among other important documents, buyers should collect Land tax paper, NID (National Identification) of the landowner, etc. If any of these papers are determined to be illegal then there is a high probability of fraud or harassment. As a result, ideally, the process should stop there and further ramifications with the government should start to resolve the issues.

2.2.1. Deed

One of the core legal documents for ROR transfer of any land in Bangladesh is the ownership document which is called the *Deed*. A valid deed in the name of the seller should have the following properties: state on the document that it is a deed, description of the surroundings of the property in the deed, contain valid signatures of a prescribed number of witnesses and should be handed over to the current owner. A new buyer should check the authenticity of the document with the help of a lawyer. For that buyer needs to visit the local sub-registry office, where an original copy of the existing deed is stored. A very important issue that should be checked if the property has been received by the buyer as an inheritance. In that case, there should exist *Bantan Nama* (i.e. Partition deed) for the property. This document states the distribution plan to the predecessors of the original owner and if anyone else could have any claim to the property.

2.2.2. Bia records

Land administration separates records of ownership and records of revenue. There are 11 administrative offices in each Upazila (sub-district). Bangladesh is divided into 64 districts among which excluding the 3 hilly districts, 61 districts have land registration facilities. Each Upazila is divided into small plots. These plots are known as *Mouza* and are given numbers called Mouza numbers. It is also known as Jurisdiction List Number (Acuity, 2020). A set of important documents to be checked before land registration is called *Bia Records*. Bia Records include all the transaction history of a property. Every time a piece of land is handed over to a new owner, a new Bia Record is created. A common practice is to check records back to 25 years. But checking the complete history of a piece of land is the safest procedure. Any piece of land is usually under government lease. So the government keeps historical records for the property. It includes a CS (Cadastral Survey – conducted in British period 1888–1940), a SA (State Acquisition Survey – conducted in Pakistan period 1956–1962), a correction of SA record RS (Revisional Survey – started 50 years after the CS and is more authentic), and a BS (Bangladesh survey/City Jarip – started in 1970-continue) (Ministry of land, 2020). CS and RS vary from property to property as they are two methods of the same survey where CS is the older version. It is recommended to verify most of the documents to transfer land ROR.

2.2.3. Mutation Khatiyan

The replacement of the title of the previous owner with the new owner is known as mutation (i.e. ownership change) and is kept as *Khatiyan*. This document must be provided for land registration and property transfer. Otherwise, the previous owner can claim ownership or transfer ownership to anyone else. A mutation is

always followed by a Duplicate Carbon Rashid (DCR) which can be obtained from the AC (Assistant Commissioner) of a land office. It is a validation for up-to-date rent receipts for the ownership of the property. The current owner has to pay the due land tax of the property as well.

2.2.4. Non encumbrance certificate

This certificate assures that the property is free from any legal liabilities or monetary concerns. In many cases, people take bank loans and purchase land and that becomes an asset-backed by a mortgage. So it is important to check this certificate to avoid future conflicts related to mortgages.

2.3. Payment

A buyer can pay the total price of the land before the registration period or can sign a pledge to pay partially and complete the payment within the coming 6–12 months. By this period, the buyer should complete the total payment and next the seller initiates the registration procedure. If any of the parties break the pledge then law enforcement should be placed or any dispute can be settled mutually as well.

2.4. Registration process

If all the due payment is completed and the registration fee is also submitted then the buyer can apply for registration at the corresponding deed registry office by presenting the receipts of the registration fee paid. A certified registration-related document can be obtained within weeks for the new buyer's record. The original sale deed/certificate requires a few months to be obtained. The change of ROR ownership must be registered in the Land Revenue Office. The property is recorded under the name of the new owner, who is responsible for paying the land taxes (i.e. Khajna) from the day it is transferred.

2.5. Ongoing digitization efforts

In Bangladesh, the first pilot project of digital land record management started in 2011. Since then there has been some progress but not significant enough to consider as a workable digitization effort. While scanning of archival documents such as maps, Khatiyan, etc. are ongoing, most of the digitization is limited to online-based application submission. People can get GPS based mapping, apply for E-Mutation or RS Khatiyan paper, can pay land tax online, and also can apply for compensation claims against their land acquisition in some places (bdnews24.com, 2020).

2.6. Problems of the existing system

The current land titling system is a lengthy procedure that takes many months to complete and involves many departments that manage an important piece of document. As a result, there is no centralized view of a piece of land. On the other hand, most of the population is not aware of the land titling related steps and can easily forget to collect an important piece of document. Such a system empowers opportunists, frauds, and middlemen to misuse bureaucratic loopholes with the help of government officials. Here we list some critical issues:

- Sometimes powerful land sharks create false documents with the help of middlemen, government officials and forcefully grab the control of a piece of land. It takes the rightful owner a very long time (sometimes years) to retain the ROR through the judicial process.
- Land sharks again can falsify documents with bribing officials and sell to land uneducated people and gain unlawful money. In return, two owners (lawful ROR, and new buyer with false documents) get into a lengthy judicial fight.
- An original landowner can make a pledge deed (Binah Dalil) with multiple potential buyers and can receive advanced partial payments from multiple buyers. Such cases are common in the civil court.
- A greedy landowner can sell a land multiple times with full payment if the registration and mutation (change of ROR) are not completed.
- Sometimes after the registration is completed, a buyer doesn't pay the due agreed amount.
- If anything goes wrong, there are only two solutions: a mutual understanding or otherwise a police case. Any police case that goes through the judicial system causes further waste of money and time (months/years).

3. Related works

The Blockchain revolution started with the advent of cryptocurrency. As time passed, it is now the age of different domains of smart contract enabled Blockchain applications. Though the world is getting accustomed to different domains of smart contract-based Blockchain initiatives such as finance applications, asset processing settlement, payment processing, internet-of-things applications, healthcare applications, media royalties, passport issues, voting mechanisms, supply chain management, 5G incorporation, AI based solution we are still in their early stage of adoptions (Bodkhe et al., 2020; Akram et al., 2020; Mistry et al., 2020; Tanwar et al., 2019). There are very few applications other than cryptocurrencies that are widely used by mainstream users. As a technologically backward country, the Bangladesh government is putting efforts to digitize many of its services such as land-related ROR archiving to ensure transparency. As a result, it is the right time to investigate the opportunities that Blockchain can bring to reduce some of the key existing problems of Bangladesh land title management. In this section, we study the state of the art practices in this field.

In the study of Graglia and Mellon, 2018 authors report requirements and procedures to adopt Blockchain technology for real state and land registries. They describe a conceptual framework of gradually integrating different levels of Blockchain solutions for land registries. The Republic of Georgia started land titling in 2016 using phase by phase Blockchain implementation to reduce corruption and mismanagement for their land ownership registries. With the success of the pilot project, a more integrated system was initiated in 2017. As of 2018, a total of 1.5 million land titles were published on the Blockchain that ensures the security and immutability of the data (Shang and Price, 2019). Their system supports land purchases, registration, and mortgage features. The overall time required to handle land titling operation is greatly reduced according to their reporting. In Vora et al., 2018 authors present a electronic health record storage model using Blockchain for Healthcare 4.0 solution. They intend to preserve the privacy of the patients as well as provide easier access to required data using this model.

Sweden started experimenting with Blockchain-based land registration in 2017 to streamline their existing system. Their main motivation was to reduce the required number of physical documents, necessary steps, and overall expense. Though their experiment demonstrated impressive result it has to go through various bargaining agencies to be practically implemented (Future, 2018). Andhra Pradesh a state of India employed a few startups to pilot land registry systems using Blockchain to ensure transparency in governance. They had secured 100,000 land

records using this procedure on a test basis. This state is a popular destination for other FinTech related initiatives such as Blockchain-based vehicle registration (Haridas, 2018). Subsequently, the United Arab Emirates (UAE) and Dubai have taken the initiative to become the world leader in adopting Blockchain technology through the "UAE Blockchain Strategy 2021". In their ongoing projects, they are working on different sectors such as energy and water, transport and logistics, economic development, tourism, safety and justice, municipality and land, health, social service, smart districts (UAE government launches blockchain strategy, 2021).

Thakur et al., 2019 conducted a comprehensive study about existing land records management system of India, how it can adopt Blockchain technology to improve the current system and possible questions that need to be addressed to move in that direction. They provide a model of Blockchain-based land titling system for India but fall short of describing the smart contract scenarios, public key infrastructure (PKI) and type of architecture (i.e. public, private, hybrid) to be adopted to implement that. As recommended by the authors of Graglia and Mellon, 2018, it is not practical to move an old model to Blockchain without laying out an incremental policy for real-life adoption. In Mukne et al., 2019 authors present another land title management system for India using permissioned Blockchain such as Hyperledger Fabric and store documents using Inter Planetary File System (IPFS). The authors mention that the biggest challenge is to move existing land records to the Blockchain system. In Hasan and Salah, 2018, authors present an Ethereum based digital asset (e.g. file, book, image, video, or music) exchange system with a proof-of-delivery mechanism using a viable PKI model. In this paper, the authors present implementation details and algorithm models to reproduce the proposed system. Table 1 compares closely related land title management systems that are described from an academic or government perspective.

Land management of Bangladesh follows a complex procedure that involves different departments, where each department handles some important parts of the required documents. Again any dispute or mortgage-related issues need to be checked through court or financial institutions. As there is no faster communication channel among different government or private entities, land uneducated people get scammed by middlemen and land sharks and very often get tangled into the lengthy judicial process. We propose a hybrid Blockchain-based land titling system to solve this information availability and transparency problem. The introduction of third-party PKI will ensure that certified parties are involved in deal-making in the presence of an arbitrator. As blocks are immutable, history blocks are chained together, and each node of the peer-to-peer network keeps a full copy of the entire blocks, transparency or availability of information is inherent. Since land is limited, title handover is lower in number as well as few critical identifier information is sufficient enough to represent land or related parties, interested public nodes can store the public ledger for a share of incentives. Later, government-approved private or public institutes will work as heavy-duty miners of the private ledger of the proposed system. It will take some time to introduce a Full Hybrid solution, hence we introduce a three-phase Blockchain adoption plan. We provide a detailed design of the public Blockchain along with required smart contracts and implemented the system using the Ethereum. Our experiments demonstrate obvious improvement over the current manual land titling process.

4. Proposed Blockchain-based land titling system architecture

The key obstacles to incorporate Blockchain technology in Bangladesh are inadequate digital literacy and government funding, proper training of the officials, transparent government budget spending, lengthy and weak bureaucracy, familiarity of public key infrastructure, necessary policies and laws from government, etc. Though the government has been working on digital land management system for a decade, it is evident from the current progress that it will take a very long time to incorporate further new technologies such as Blockchain. Hence, we propose a phase by phase incremental adoption of Blockchain technology in the land title management process (Fig. 2). In the first phase, we introduce Public Blockchain with simpler and easier GUI for mobile devices. Fortunately, Bangladesh has over 160 million mobile subscribers and over 103 million internet subscribers (Commission, 2020). Later a smaller footprint of the Hybrid Blockchain will be introduced that will eventually materialize to the Full Hybrid Blockchain overtime. The following sections provide details on their design procedure.

4.1. Phase 1: public blockchain

The first obstacle in the adoption of Blockchain technology for land title management in Bangladesh is the digital illiteracy of the mass people. Since people are well versed with mobile devices and the internet these days, it is a wiser move to incorporate simple mobile internet based UI to create timestamp blocks of regular ROR handovers in the public ledger. The buyer and seller will be identified using their national identification number (NID) or birth certificate number (BCN) and the land will be identified using division, district, thana, JL No, Plot No, Khatiyan No, etc. The related hash will be generated and stored in the public ledger for regular land ROR operations initiated by the government. This public ledger is a timestamp manager of ongoing or previous ROR handover activities. We know that a significant amount of land is unregistered and handed over without any due procedure (Rahman and Hossain, 2020). Such ROR handover creates judicial burden overtime.

People voluntarily participate in this public ledger transaction, which will be enforced by government officials. Any regular registration must be logged with due identifiers using a small fee with the presence of land office officials. Similarly, ongoing disputed cases or loaned/leased land will also be added to the public ledger by the relevant government or private institutes. It is expected unregistered lands will also be logged in the public ledger as the benefit of having such a simpler application outweighs the mere fee. Only government officials or notary registers are allowed to write in this public ledger to curb fraud entries. The important issue in this model is that regular common people are with limited computing capabilities, hence mining the public ledger can be an issue. Since land is limited and the number of transactions is further limited, so the size of the public ledger can be managed by a willing group of public. Also, the person who acts as a public miner will be benefited from the transaction fee disbursed by the deal handshaking and searching operations. In the public Blockchain, new buyers can easily check the history of a particular land and its current status using a small fee. Before any land ROR is officially getting a new title owner, the land officer will check whether a relevant public block was created on the Blockchain. This is to ensure that the parties involved in the transaction get enough motivation to log into the public ledger. Since the digitization is a slow process, it is important to initiate public ledger logging for future incorporation of second phase operation. Any startup approved by the government or a government body such as A2I can take the initiative to build this public Blockchain.

4.2. Phase 2: hybrid blockchain

The first phase introduces people with Blockchain technology and its benefits. It encourages the government to incorporate

Table 1
Comparison of Blockchain-based land title proposals

	Shang et al. (2019)	Thakur et al., 2019	Mukne et al., 2019	Proposed System
Country	Georgia	India	India	Bangladesh
Challenge	Corruption control	Transparent ownership	Digitized	Archive digitization ongoing
Digitization Level	Land database available	Land database available	Land database available	Digitization is sloth
Proposed model	Incremental two phase	Single phase	Single phase	Incremental three phase
Blockchain Architecture	Public	Public or private	Permissioned Blockchain	Phase one public, next two phases hybrid
PKI	N/A	Certificate authority	OAuth	Multi-party
IPFS	N/A	N/A	Enabled	Enabled
Project implementation	Bitcoin as a layer	Conceptual study	Hyperledger Fabric prototype	Ethereum as a layer at public phase
Government Initiated	Assigned startup	Academic	Academic	Academic
Experimental Result	Phase one successful now moves to phase two	N/A	Prototype	Compared with benchmark

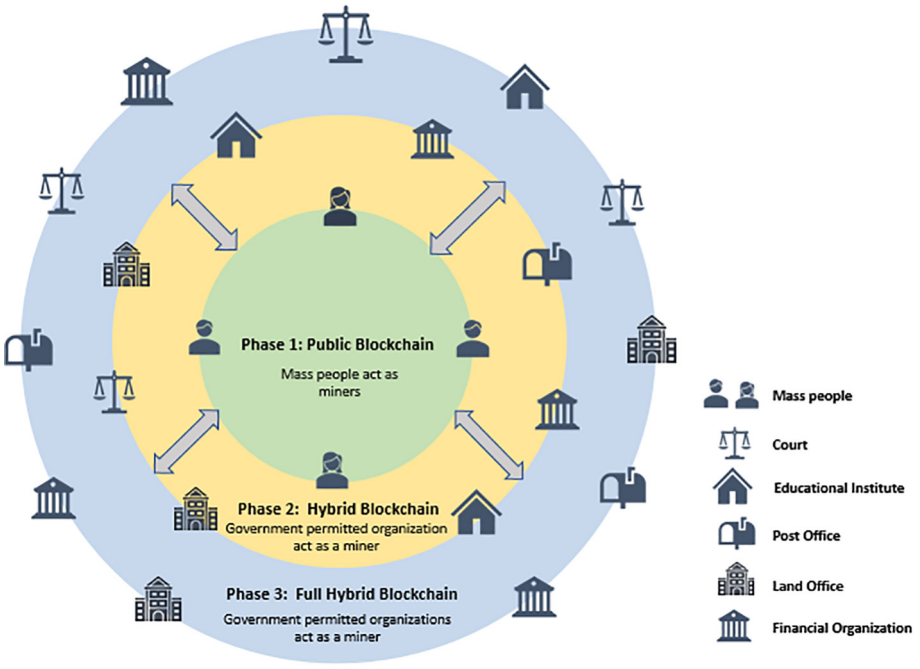
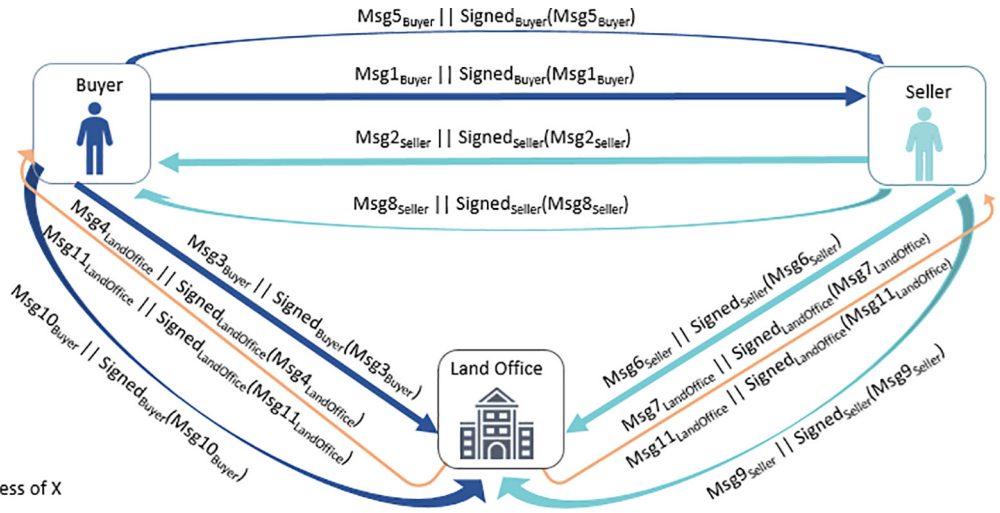


Fig. 2. Proposed incremental Blockchain adoption model for land title management of Bangladesh.

advanced technology into its land digitization process. As bureaucracy is difficult to move and technology is high paced, the first phase prepares people and government for second phase Hybrid Blockchain and later the ultimate solution that is Full Hybrid Blockchain-based land title management. In our model, we propose PKI based trusted communication among involved parties: buyer, seller, and land office in the second phase of hybrid Blockchain following (Hasan and Salah, 2018; Hasan and Salah, 2018). As the digitization effort of the land record system is ongoing from the government side, at this phase slowly some public offices and private offices will join the Blockchain mining effort. Private Blockchain ledger will be introduced on a small scale that will gradually incorporate the available history data of the public Blockchain. This is like a digital survey from the government, where PKI will be incorporated. People have to contact Certificate Authority (CA) to collect individual public–private keys (BCC, 2020). Since mass people will be educated on the benefits of new technology and experienced some benefits already, it will be easier for the government to educate people about the importance of PKI. In Fig. 3 we describe how buyers, sellers, and land office will use a trusted communication channel to agree or disagree on a potential deal. This multi-party PKI will ensure that the officer responsible for the deal-making is also included in the transaction procedure. It will help to audit transactions if required. Fig. 4.

Trusted public or private organizations will work as the key miners in the second phase. Permissioned nodes of the private ledger will have the high-end capacity to complete the mining operation. Whereas, there will be some trusted monitors such as public universities, courts, post offices, banks to provide important key information passage to the public ledger of the mass miners. The fee that is collected by the government will be shared with the trusted nodes participating in the private ledger as well as with the public miners. The advantage of this model is that the private Blockchain will ensure that more data related to any land such as a digital map, digital Khatiyan, deed, Parcha, mutation documents, etc. can be linked to the mined block or modified later when more documents will be gradually digitized by ongoing government efforts. This private ledger is more of an official record of the government similar to the status of RS, SA, etc. surveys. At this phase, documents so far digitized will be accessible through the API



- EA_X = Ethereum Address of X
- PK_X = Public Key of X
- $Msg1_{Buyer} = EA_{Buyer} || PK_{Buyer} ||$ "Request for wallet Account Number"
- $Msg2_{Seller} = EA_{Seller} || PK_{Seller} || EA_{Wallet}$
- $Msg3_{Buyer} = EA_{Buyer} || PK_{Buyer} ||$ "Verify Wallet Account Number" $|| EA_{SellerWallet} || EA_{Seller}$
- $Msg4_{LandOffice} = EA_{LandOffice} || PK_{LandOffice} ||$"Verified or Wrong Wallet Response "
- $Msg5_{Buyer} = EA_{Buyer} ||$ PKBuyer $|| EA_{SellerWallet} || Token_{Khatiyan} || Token_{Plot}$
- $Msg6_{Seller} = EA_{Seller} || PK_{Seller} || Token_{Plot} || Token_{Khatiyan} ||$ "Verify Plot and Khatiyan Token"
- $Msg7_{LandOffice} = EA_{LandOffice} || PK_{LandOffice} ||$ "Verified or Wrong Response"
- $Msg8_{Seller} = EA_{Seller} || PK_{Seller} ||$ "Acceptance or Reject Response"
- $Msg9_{Seller} = EA_{Seller} || PK_{Seller} || Token_{Khatiyan} || Token_{Plot} ||$ "Full Price"|| "Pledge"|| $EA_{Buyer} ||$"Acceptance Agreement"
- $Msg10_{Buyer} = = EA_{Buyer} || PK_{Buyer} || Token_{Khatiyan} || Token_{Plot} ||$ "Full Price"|| "Pledge"|| $EA_{Seller} ||$"Acceptance Agreement"
- $Msg11_{LandOffice} = EA_{LandOffice} || PK_{LandOffice} || Token_{Khatiyan} || Token_{Plot} ||$ "Full Price"|| "Pledge"|| "Tax" || "Total Cost" || $EA_{Seller} || EA_{Buyer} ||$"Agreement Witness"
- $Token_{Plot}$ = keccak256(Division, District, Thana, JL No, Plot Number)
- $Token_{Khatiyan}$ = keccak256(Khatiyan Id, $Token_{Plot}$)

Fig. 3. Off chain communication exchange protocol among buyer, seller and arbitrator land officials.

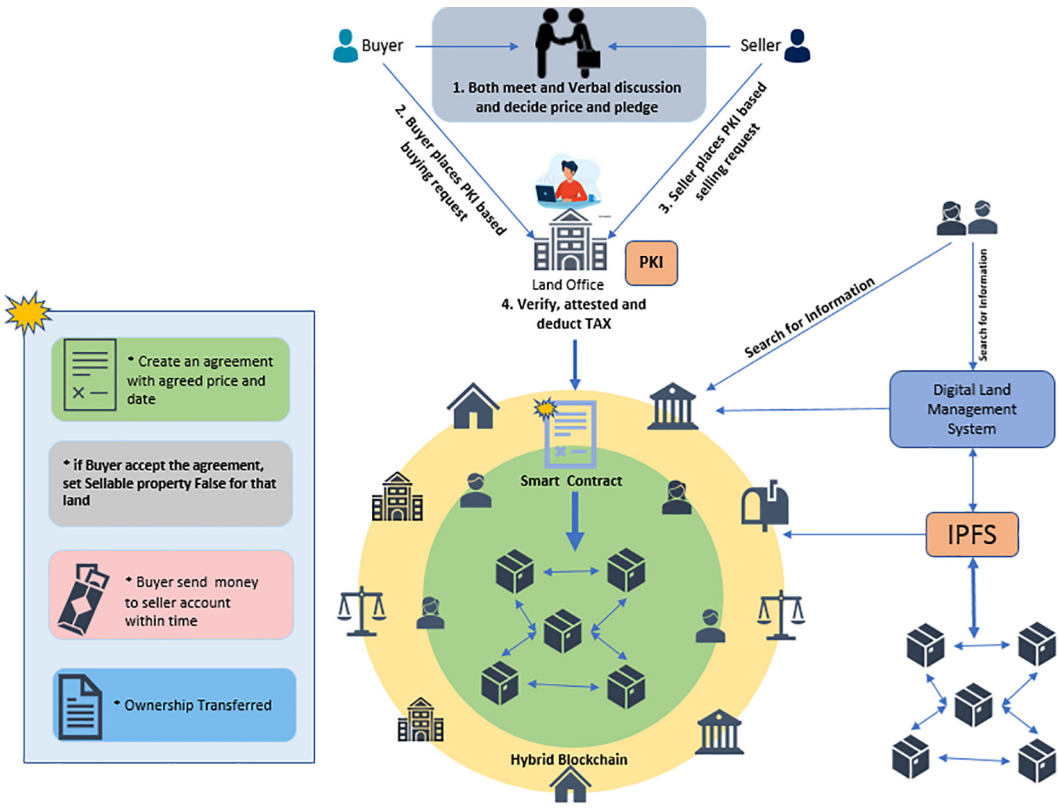


Fig. 4. Full Hybrid Blockchain (Phase three) architecture of land titling system for Bangladesh.

provided by the government to the different branches of the government or private institutes if they require any piece of digital evidence. But, at this stage, the documents are not stored in IPFS. As key information is available in the public ledger, mass people can easily access more trusted land record data with some little fees. This facility will reduce data checking requests in the union land offices.

4.3. Phase 3: full hybrid blockchain

From phase one people and government get to learn about the benefits of adopting Blockchain technology in land deals. On the other hand, phase two ensures the government takes the right step towards the institutional adoption of Hybrid Blockchain. From these learning experiences, it is expected that the mass people, government employees, and the government infrastructure will be capable enough to handle phase three Full Hybrid Blockchain. In this phase, more public and private institutes with high computing capacities get involved in the private ledger mining operation to share a part of the fee collected by the government. Private Blockchain ensures that trusted nodes can modify the blocks when full digitization of the current documents of the government is completed. In this final phase of Blockchain, digitized documents will be stored in the distributed file system such as IPFS (Benet, 2014; Akther et al., 2007). IPFS is a peer-to-peer file-sharing system where any file if stored receives a unique hash key and the data blocks are distributed in the file system. The distributed hash table is organized as a Merkel Tree DAG. This will ensure that untrusted nodes can not alter a digitized file from the central place of access. The public or private organizations participating in storing the IPFS documents will get a share of the fee that is received by the government every time such a document is requested by any user. These users can be new potential buyers, the current owners, or others who are searching for information about a particular piece of land. As a result, data lookup service will be available day and night except for the registration system. With this model, the government can easily find unregistered lands and can also reduce the undervaluation of land and TAX loopholes. The Full Hybrid Blockchain ensures more transparent governance for the land titling process.

5. Public Blockchain of proposed land titling system

Public Blockchain in the first phase only works as a timestamp logger of ongoing land handovers, current ownership, dispute, or financing events. In our proposed system, every user should open an account in the central system in the first place. A user can be an owner/potential owner of the land, designated land official, judicial officials, finance officials, and notary registers. Whenever a new block is created in the public Blockchain, it stores related NIDs of the parties such as buyer, seller, and arbitrator. Any person can check a particular land's details and also monitor operations related to his/her land using a small fee, which will be shared between the miners and system providers. The following sections describe different segments of the system in detail.

5.1. Data structure of smart contract

In the first phase, a smart contract contains user detail, plot detail, and Khatiyan detail in the data structure. User detail contains all the basic user information such as full name, parents name, address, date of birth, national identifier (NID) or birth certificate number, etc. Plot detail contains the address of land titles such as division, district, Upazila, Mouza number, plot number, etc. Plot number is a unique identifier of a piece of land under a certain map. Similarly, Khatiyan detail contains records of rights of a plot. Khatiyan contains the percentage of land any owner owns. So, we can query the smart contract to find a certain Khatiyan and see all related details. In the public Blockchain miners are common people. As a result, it is important to reduce the required smart contract space. A land plot can be uniquely identified using the hash value of division, district, Mouza number (i.e. JL no), and plot number. Similarly, Khatiyan information can be represented as the combination of the hash of the Khatiyan number and the hash of plot information. When a smart contract is deployed into the Blockchain, its storage space is almost empty. After the first deployment, the administrator should add user and plot information into the Blockchain. Later Khatiyan information will be backed by this fundamental information to reflect the ownership.

5.2. User account creation

In order to create a user account, a user has to go to the land office or notary service provider with NID (National Identification)/Birth Identification card and other required documents. Once verification is completed, a new user will be created in the Blockchain. The account contains the information of the creator as well to enforce audit possibilities. A user can update his/her password when required (Fig. 5). Since the account is associated with an ID, only one account is possible for each user. Once an account is mined, a user receives a wallet that stands empty at the beginning. But he/she can buy Blockchain currency from the land office to conduct operations in the system.

5.3. New land records mining in public Blockchain

A legitimate owner can request the land office to record a land against his/her name but he/she needs to provide required documents. Later a land official will verify the documents and will assign ownership against the user account using his/her official account. This extra information will enable auditing in the future if required. A land that contains an owner is called Khatiyan. In this case, at first, plot information is added to the Blockchain which is later attached to its legal owner participating in the public Blockchain.

5.3.1. Plot (Dag) mining

In order to mine a new plot in the Blockchain, the first step is to take the required plot details (Fig. 6) and calculate the hash. If the hash exists in the current system then the transaction will abort. Otherwise, it will follow through the mining steps and will complete a valid transaction.

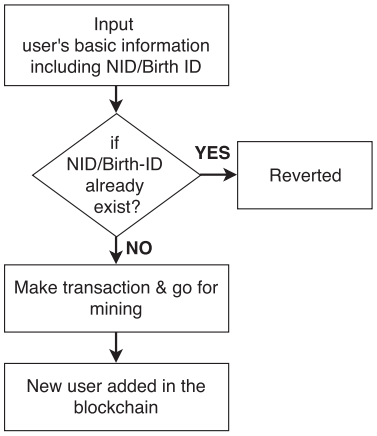


Fig. 5. User account mining procedure.

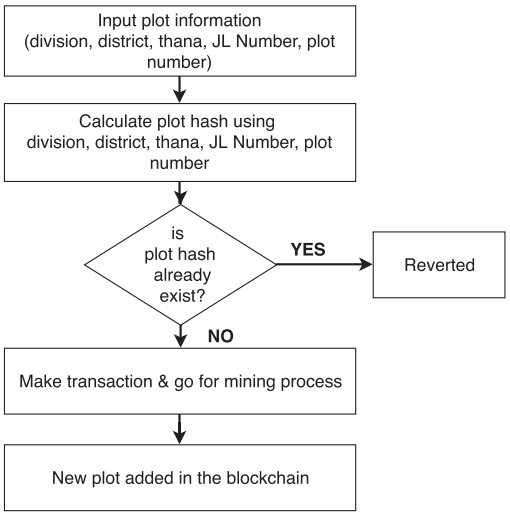


Fig. 6. Plot (Dag) mining in the public Blockchain.

5.3.2. Khatiyan mining

Record of rights of the land i.e. Khatiyan should also be mined in the Blockchain. There are two types of Khatiyans: new Khatiyan and mutated Khatiyan. In order to mine a new Khatiyan, the proposed system requires an existing Khatiyan number, plot hash, list of owners, percentage of each owner in new Khatiyan, etc. From Fig. 7, we see that the system first calculates a new Khatiyan hash using current Khatiyan number and plot hash. Later it verifies the plot hash and the users. If the users and plot exist in the system then Khatiyan hash is checked. If it doesn't exist in the system then a new transaction occurs for new Khatiyan generation and after the mining process is completed new Khatiyan is added to the Blockchain that tracks back to the older Khatiyan information.

5.4. Land purchasing and registration process

Fig. 8 shows the smart contract to be used for the land purchasing process. The Buyer and the seller must agree to each other's terms and conditions in real life and should settle for a price. If the buyer can pay the total amount and registration fee at the registration time then the process will continue. Otherwise, they set a pledge (Bayna Dolil) for partial payment and set a date to complete the pending balance. They should communicate with the land office after setting the price. The land office verifies the documents related to the property. If the seller has the legal ownership, land office logs into their account and creates an agreement with the pledge and rest of the money (convert automatically to land currency) with two different dates since the buyer can't complete a full transaction at a time. If he/she can pay the total amount at a time then pledge is set to zero and the rest of the amount will be set to the price amount with the date. The seller has to agree to the pledge through his/her account. When he agrees to the pledge, the property's *sellAble* field will be set to *False* and it can't be sold while this agreement is alive. If the buyer accepts the pledge, he/she has to pay the amount within the fixed date. To pay for this money, he/she has to go to the land office and buy the land currency. When this currency is paid to the seller, the seller can't cash that until the total price of the land is paid. This currency is kept secured in *Government Land Purchasing Account* against the agreement which is the 3rd wallet account. If the buyer failed to pay the pledge money during the given time frame, the *sellAble* field of the land will be set to *True* and the agreement will be void. When the buyer completes the pledge, a new contract is created with the rest of the money and a new date, and the registration process restarts. Later ownership of the land is handed over with the new agreement. Otherwise, pledge money will be redeposited to the buyer's account and *buyable* property will be reset to *True*.

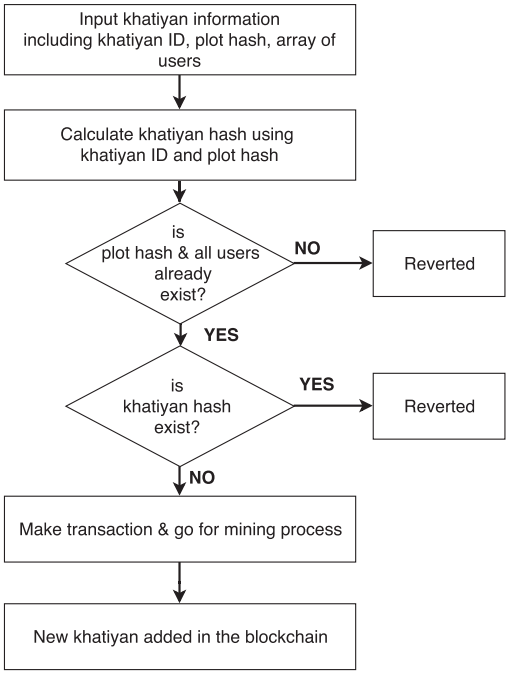


Fig. 7. Mining process of new Khatiyan in the proposed system.

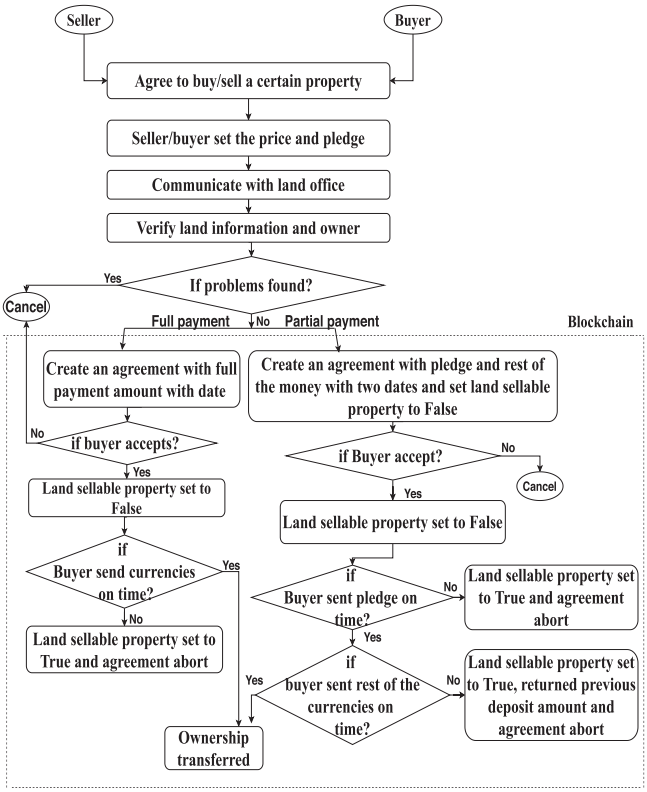


Fig. 8. Proposed land purchase and registration model.

5.5. Record of rights (ROR) transfer

ROR means a piece of Khatiyan information already exists in the system mapped with existing owners. ROR transfer can occur in

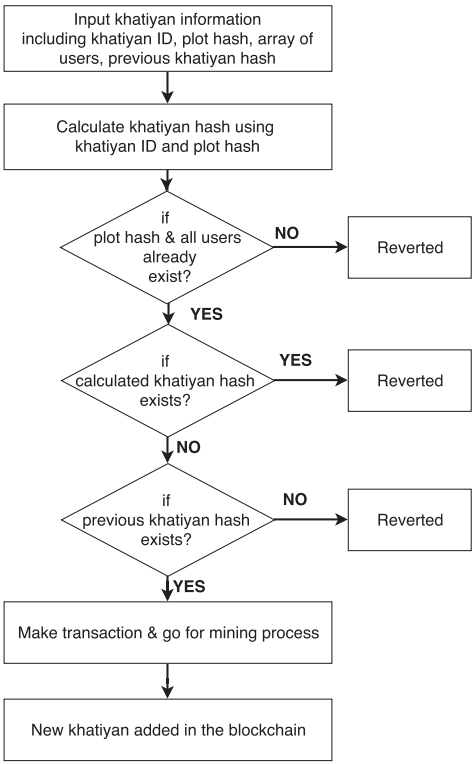


Fig. 9. Khatiyan mutation mining in the public Blockchain.

the cases: when a seller is selling the land to new potential buyers, when someone gifts the immovable property to a new owner and when land is inherited according to law. This process of ownership transfer is handled by *Registry Process* and such a Khatiyan is called *Mutated Khatiyan*.

When a user decides to sell land to other users or need to transfer ownership, there is a need to register new ROR for the new owners. To log this new type of Khatiyan into the Blockchain, designated land officials first check for the previous Khatiyan hash along with the other data that are given for new Khatiyan entry (Fig. 9). If the looked-up Khatiyan already exists then only ROR transfer will start.

5.6. Searching records

As all the data is recorded in the public Blockchain, it can be easily accessible through the right interfaces. But searching for thousands of blocks will take a long time. For this reason, in the public Blockchain, we only store required useful information that can verify the current status of a piece of land. In order to search a Khatiyan, a user needs to provide necessary required details that will be translated to the unique Khatiyan hash and all the historical data about the land will be available for a searching user with a small amount of fee. Similarly, we can get user and plot details from the Blockchain with the necessary privacy.

6. Prototype implementation of the public Blockchain

Ethereum (Ethereum, 2020) is a decentralized and open-source distributed computing platform that allows creating smart contracts and is very popular for the third party distributed application development. For our public Blockchain prototype development, we have used Ethereum to deploy land title smart contracts. We also used Solidity (Solidity, 2020) that is a scripting language to write Ethereum code,[1] Ganache-cli Ganache-cli, 2020 as a local test network, Remix (Remix, 2020) as an online IDE that executes solidity code, HTML and CSS for the web user interface, web3.js as the javascript library to interact with remote Ethereum node using HTTP or IPC connection and Metamask (Metamask, 2020) to interact with Blockchain from a browser.

6.1. Smart contract development

Fig. 10 represents the class diagram of the smart contract objects (User, Khatiyan, Plot, Wallet) that are implemented in the Ethereum platform. *User* object contains personal information, address, and NID. This class supports some interfaces to retrieve specific user's details, currently owned lands, and whether a user exists or not. The mining event of *User* class is new user creation in the Blockchain. The *Plot* class contains identifier details such as division, district, thana, JL no, plot no, etc. and supports functions to check plot existence, finding plot by ID or hash. The mining event of this class is the creation of a new plot using the hash value. Similarly *Khatiyan* class contains identification details, plot hash, several ownership items, etc. Public functions supported by this class are related to Khatiyan existence, retrieval of Khatiyan details using ID or hash value. The mining event supported by this class is related to Khatiyan creation in the Blockchain. On the other hand, *Wallet* class contains user information and validates ownership. The mining event is related to Blockchain currency payment for various land titling related operations. Similarly, *Khatiyan* contains required identifier information, multiple ownership support, ownership handover mechanism. On the other hand, a *Plot* object contains location and identifier information. Every *Wallet* object is tied to a *User* of the Blockchain.

Relation of objects in Solidity is maintained using the mapping of structures. Mapping in Solidity is a key-value pair where every structure has a unique field as key and another structure as a value in the respective mapping. Whenever we need a unique field with combined values, we calculate a hash of those combined fields using Keccak256 (Keccak256, 2020) hash function and used as the key. In order to manage storage space, string/text data type can be represented as *bytes32* data type for mining. In that case, retrieved *bytes32* type data from Blockchain is converted to *string* type for user readability. Any data-heavy write operation in the Blockchain requires a lot of gas (a unit that measures the amount of computation effort) and sometimes it can give gas limit error and fails to pass the mining process. So, we used a minimal set of data that is representative enough for land or owner.

6.2. System functionality

Our prototype implementation centers around five key functionalities: user creation, plot creation, Khatiyan creation, land registration process, and Khatiyan mutation (ROR transfer). At first, an administrator adds users and plots using the prototype system. Later the system admin can create a new Khatiyan using Khatiyan ID, plot hash, and user id along with their percentage of ownership of a Khatiyan. A Khatiyan block stores the information about the land and its owner. In order to use Solidity easily, we developed a hash calculator to calculate the plot hash from input details. Using this hash value an admin can retrieve Khatiyan hash. Khatiyan hash is used to search details of a specific piece of land in our public Blockchain implementation. Relevant ownership information is also revealed from the Khatiyan details.

As mentioned earlier *byte32* based text data storing reduces storage and gas requirements. Initially, the system stores no Khati-

[1] Prototype system, https://github.com/dgted/landblockchain.

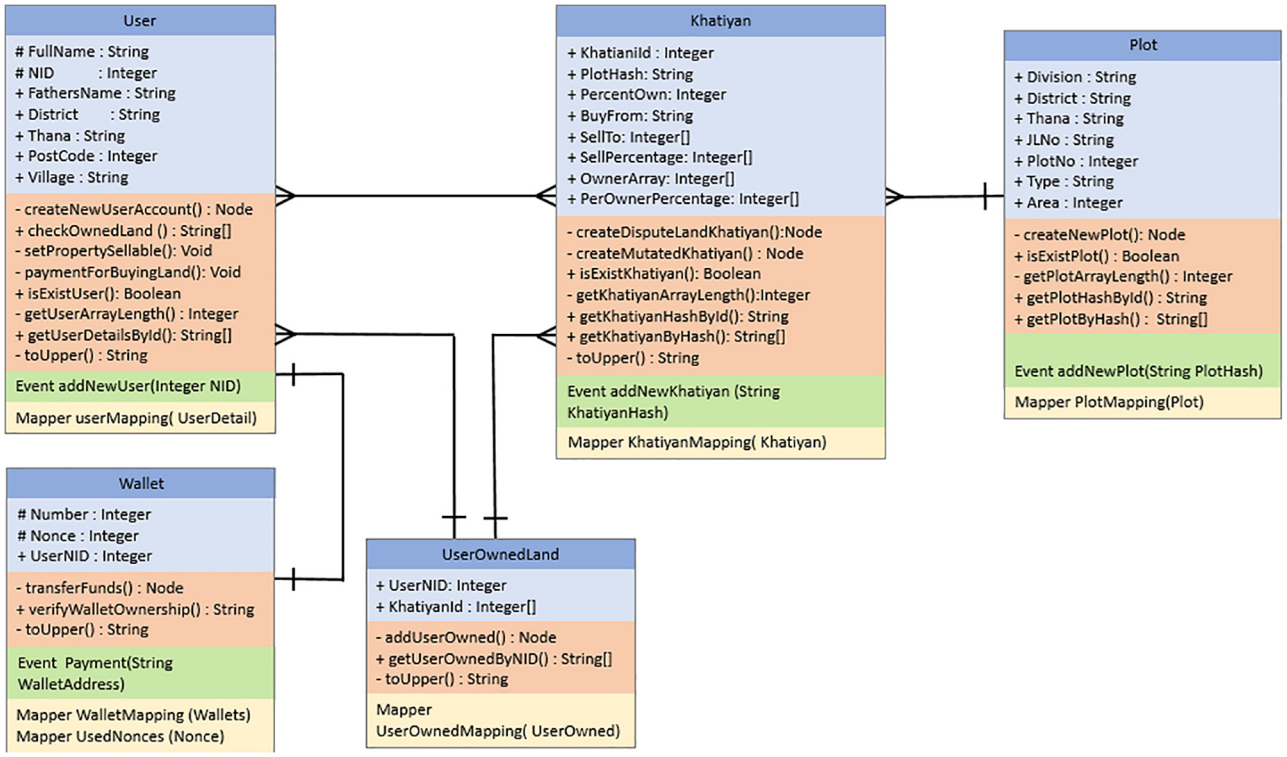


Fig. 10. Class diagram of the smart contract developed for Phase one Public Blockchain.

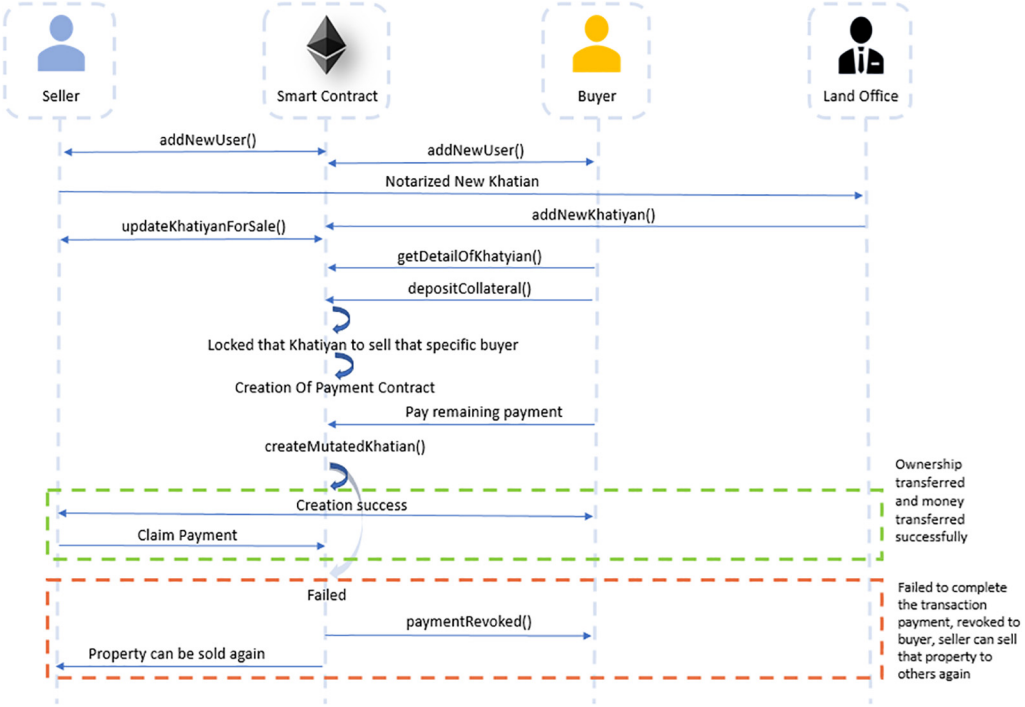


Fig. 11. Sequence diagram of Khatiyan Mutation action using the Public Blockchain model.

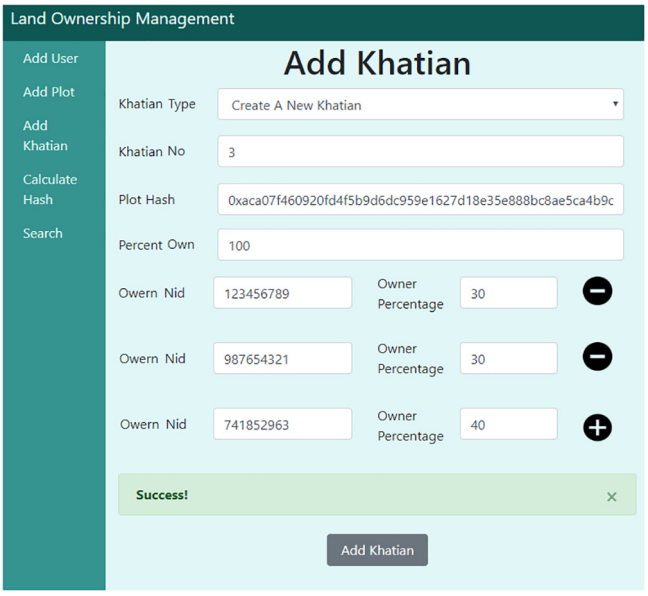


Fig. 12. Storing Initial Khatiyan for Owners.

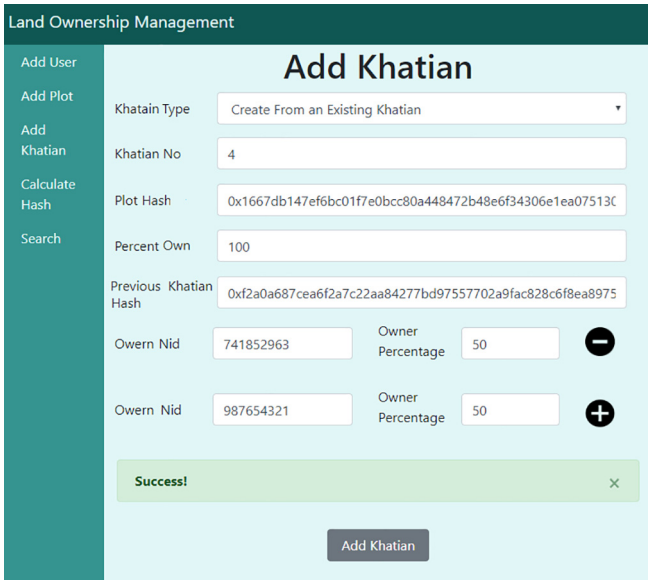


Fig. 13. Khatiyan mutation user interface.

yan. As a result, we have to start with plot information and user information to construct a Khatiyan entry. Fig. 12 shows GUI to create initial Khatiyan entry for multiple owners along with their percentage of ownership. Once there are Khatiyan records available for purchasing, a user can sell/donate respective property to other users of the system. Such operation will create new Khatiyan entries. A new owner is assigned through the GUI of Fig. 13. Internal data structure appears like the mapping of Table 2. Fig. 11 shows a detailed sequence diagram of a Khatiyan related operation using our prototype system.

We have developed a JavaScript-based hash calculator that is equivalent to Solidity's Keccak256 hash function. A user of the system can calculate plot and Khatiyan hash using this tool if he/she has required data to search entries in the Blockchain. A user can search for Khatiyan information by providing Khatiyan hash on the search page (Fig. 14). From the search result, one can see the details of the users and the plot of that Khatiyan by clicking on users' NID and plot hash respectively.

7. Experimental results and discussion

In this paper, we propose a phase by phase Blockchain adoption model for land titling problem of Bangladesh. Currently, Bangladesh uses a paper-based traditional and cumbersome land management policy, where different departments struggle to synchronize their works resulting in versatile kinds of fraud. Frauds lead to judicial litigation that takes months and years to settle, which is the prime cause of civil cases in the country. In order to solve this transparency, synchronization, and accessibility problems, we choose a phase by phase adoption of a Hybrid Blockchain-based solution. We have implemented a prototype model of the phase one public Blockchain using Ethereum. For the deployment of our smart contracts, we have used two networks: Local Test Network and Ropsten Live Test Network of Ethereum. We have conducted various types of tests on these test networks.

In our experimental setup, we have handled multiple ownership scenarios for a single piece of land. Every write operation is a transaction in the smart contract and eventually in the Blockchain. Each transaction is packed into a block, and stored in the Blockchain. All of our write operations are safely guarded by thousands of nodes running the actual Ethereum Blockchain. For the local test network, we use Ganache CLI which provides ten dummy Ethereum account with 100 ether per account. Deployment of smart contracts is done using Metamask for the local tests. We set a gas limit for Ganache CLI 1000000000. During the initiation of Ganache CLI, there are ten accounts, ten private keys, and a listening port. In this case default port is set to 8545 and Truffle is directed to write in this port in order to work with Ganache. Once we compile or deploy the smart contracts or any transaction occurs, history is visible in the Ganache terminal window. We used the Ropsten test network for live Ethereum tests that are managed by a large number of volunteers. We deployed the Remix code in Ropsten via Metamask. Here Blockchain operation costs some mining fee. Computational power is also required to run the smart contract. Both of our experimental results are presented in Table 3.

Since one of our goals is to make the proposed solution simpler and affordable, we use a less costly approach to store text values. Instead of using string type, we use the *bytes32* representation of that data which is much cheaper to store in the Blockchain. In Table II, four different transactions are given along with their gas usage and estimated cost in USD. During our experiments, 100 gas used to cost about 0.00004 USD, where 1 USD is approximately around 80 BDT. Gas is converted to Gwei, then to ETH, then to USD, and finally to BDT. So, the change of ETH value varies the cost of operations. Gas usage can be updated depending on how much data are supplied by a little margin in cost. We present the average costs of our operations using our prototype. It evidently provides a cheaper solution with a high level of transparency, synchronization, and accessibility (Table 4). Required time for each operation is merely a few minutes which is negligible in terms of comparison with current requirements of many times of travel and months to complete the registration and mutation process (Saif and Hawlader, 2019).

7.1. Discussions

The key advantage of using Blockchain for land title management is that data is immutable, can be traced back in history that

Table 2
Khatiyan mutation database structure.

Khatiyan Hash (bytes32)	Khatiyan ID	Plot Hash (bytes32)	Percentage of Plot in This Khatiyan	Migrated from Khatiyan Hash (bytes32)	Migrated to Khatiyan Hash (bytes32)	Percentage of Selling	Owner NID	Owner Percentage
0xf2a0a687 cea6f2a7c2 2aa84277b d97557702 a9fac828c6 f8ea89750a 2653ada6	2	0x1667db1 47ef6bc01f 7e0bcc80a 448472b48 e6f34306e1 ea075130ff f546d7241	0%	....	0x2952f283 86a85977bf 6bad4052a 68e303253 039d452a3 d2baee39a 6270f12430	100%	123456789	100%
0x25b4401a a6ea7d8e08 beb0f142d6 1d08ed0003 d224d235b9 b10ce935c8 58e1c3	3	0xaca07f46 0920fd4f5b 9d6dc959e1 627d18e35e 888bc8ae5c a4b9d13329 73e6ce	100%	....	....	....	123456789 987654321 741852963	30% 30% 40%
0x2952f283 86a85977bf 6bad4052a 68e303253 039d452a3 d2baee39a 6270f12430	4	0x1667db1 47ef6bc01f 7e0bcc80a 448472b48 e6f34306e1 ea075130ff f546d7241	100%	0xf2a0a687 cea6f2a7c2 2aa84277b d97557702 a9fac828c6 f8ea89750a 2653ada6	....	....	987654321 741852963	50% 50%

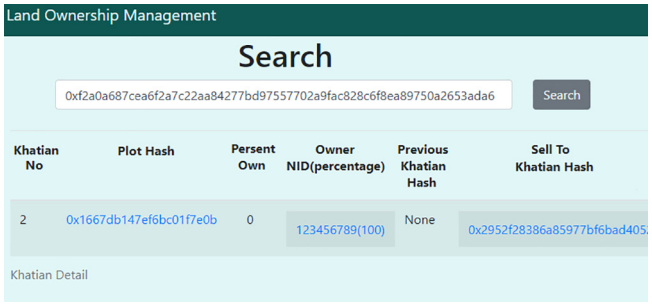


Fig. 14. Khatiyan Lookup Interface.

resembles the land records matching of Bangladesh. As a result, fraud actors are not able to tamper any of the histories. Also, simplified access of the public Blockchain using mobile-based GUI ensures easier accessibility for people who are land illiterate. The number of required travels, required time to complete ROR handover, and the cost of searching or other Blockchain operations is very negligible compared to the existing scenario of the country. In our prototype development of the first phase of public Blockchain our experimental setup demonstrates the efficacy of the proposed model.

But, in order to deploy a real-life setup, the government needs to play the main role. As we do not represent any government entity and this research work is an academic study, it is in the hands of the government to further experiment with the next phases of the proposed system. We also need to consider scenarios such as multiple land titles in a single Khatiyan, Khas land, or lease land management using the model. In our experimental setup, Ethereum Blockchain took around 1.5 GB storage space, which would eventually grow larger for real-life public Blockchain adoption by common people. So not every person can be a public Blockchain miner. Also in our proposed model, larger data blocks will be handled by the private ledger part of the Hybrid Blockchain. Usually, a manual land survey takes 20–25 years to complete. As a result, the adoption of public Blockchain is a good move in the right direction which will be helpful for the government's current digitization effort. It should be noted that the government also needs to devise various policies and laws, consider creating land-related

Table 4
Comparison of proposed system with available benchmark data.

	Current Land Mutation Saif and Hawlader, 2019	Public Blockchain based Mutation
Average Time	39 days	1–2 visits + 10–20 min online operation
Average Cost	1270 BDT	Online operation around 20 BDT + Travel expense
Average Visit	4 Visits	1–2 maximum visits to verify documents

Table 3
Cost of Developed Smart Contract Transactions.

Data Type	Test Network	Avg. cost per Network (Gas)	Final Avg. Cost (Gas)	Average Cost (BDT)
Contract Deployment	Local Test Network Ropsten Test Network	3126421 3042907	3084664	116.46
Adding new user operation	Local Test Network Ropsten Test Network	212470 218830	215650	8.14
Adding new plot operation	Local Test Network Ropsten Test Network	168362 152715	160539	6.06
Initial Khatiyan entry operation	Local Test Network Ropsten Test Network	415996 468819	442408	16.70
Khatiyan mutation operation	Local Test Network Ropsten Test Network	490781 507886	499334	18.85

Blockchain currency. From the experiments, we see that the Gas price varies with ETH value which will not be acceptable for the people. Furthermore, common people should be informed, educated, and counseled about the new lifestyle of managing their sacred lands with digital records. It is also important that the government finds a better and useful way to securely record and manage the PKI as well.

8. Conclusion and future works

Land title management is a cumbersome and lengthy process in Bangladesh that lacks synchronization among different government departments. Land sharks, middlemen, and corrupt officials take this opportunity to create falsified documents to commit various land-related crimes. These create burdens on the judicial system of the country with most of the civil cases. In this paper, we propose a Hybrid Blockchain-based solution that provides synchronization among stakeholders, ensures transparency of data, enables ease of access and manages immutable transaction records. Considering the immature technological status of the government and general people, we propose a three-stage Blockchain adoption model that starts with public Blockchain and finally forms into the large scale Full Hybrid Blockchain. We provide a detailed design of smart contracts for the public Blockchain and implemented a prototype system using the Ethereum Blockchain testing network. Our experiments clearly demonstrate that the proposed solution is cheaper, faster as well as user friendly for both land management authority and common users. It is important to note that this research is an academic endeavor and does not relate to any government bodies. Our observations show that the government has to introduce new policies and laws about Blockchain, public key infrastructure management bodies, improve capacity, train officials, and educate general people to successfully incorporate this high-tech solution.

Possible future work can be Hybrid Blockchain implementation and the introduction of land-related currency. Security attacks simulation and possible deterrence can be another future work on the system. An empirical study of a pilot project can be very insightful. Another important work would be smart contract security, vulnerability analysis, and proper PKI management.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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