Blockchain technology for land registry management in developing countries

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***Abstract*—Blockchain technology provides a secure framework for dealing with digital assets, conducting financial transactions, and managing property information. The traditional process of land registration often suffers from inefficiency and complexity, primarily due to the involvement of multiple intermediaries, which increases the risk of fraudulent land transfers. In developing countries, property records are often not easily accessible, relevant processes are susceptible to corruption, and have a lengthy turn-around time. This not only leads to disputes over land ownership but hinders the economic activity, such as, disused land, legal complications for agricultural loans and mortgages. By leveraging blockchain technologies, land ownerships can be transparent, supporting accessible and trustworthy land transfers with a reduced risk of fraud and corruption. We propose a blockchain based solution to facilitate access to land documents for verifying land ownership prior to transferring funds from a buyer to the seller. The transparent and unalterable public ledger can thus validate and preserve the land transactions.**

Keywords—land registration, trustworthy system, decentralized application, smart contract, immutable, land registration, consensus

I. INTRODUCTION

Land registration involves multiple parties and government organizations to implement a series of long drawn out complex procedures [1]. The land registration process could be paper based, comprising digital records, or more recently and for some developed countries, a blockchain-based system. The paper based records and current method of storing land titles have many limitations like data tampering, security risks, vague procedures, and potential disruptions. The digitalization of records alleviates some of the problems of paper-based systems, but still has the issues associated with a single point of failure due to centralized records [2]. Without a reliable custodian, a digital record is no better than a paper-based record. A blockchain based system is decentralized and the flexibility of the design choices, make it possible to adapt it to the suit different land registry systems.

The payment transactions on the Internet depend on trusted third parties, which instead could rely on cryptographic proof allowing any two parties to engage in a transaction without a trusted third party [3]. Blockchain is useful in any trustless system with multiple parties, and provides an accessible and full record of all transactions [4], [5]. Transactions are verified through digital signatures, guaranteeing authenticity, and protecting against tampering. Blockchain is a highly secure method of documenting information, utilizing a distributed ledger technology (DLT) with transaction records, called blocks, spread across a network of computers. Each block has a unique identifier and holds previous block's information. The blockchain operates through peer-to-peer nodes, forming a decentralized and resilient system. Blockchain is ideal for registering and managing long term data, such as, land records [6]. The advantages of blockchain technologies have resulted in many efforts to integrate blockchain into land record management systems for enhanced security and reliability.

The United Arab Emirates (UAE) has adopted a holistic blockchain strategy for Dubai, making it the first city powered by blockchain, and claiming that, "Adopting Blockchain technology Dubai stands to unlock 5.5 billion dirham in savings annually in document processing alone — equal to the one Burj Khalifa's worth of value every year [7]. The current and the improved blockchain based process for real estate transactions in Sweden could have the property title registration process time reduced from 4 months to few days [1]. The blockchain based land registry in Sweden has the transactions open sourced that can be verified by anyone [1]. A successful approach for the blockchain based system adoption must be supported by the IT readiness and political will of the organizations for the emerging technologies [8], [5]. In the developing countries, the stakeholders and officials who perceive the improved government processes as threat, are opposed to such improvements [8] and can downright sabotage the success. This can be evidenced and analysed for Honduras, where the blockchain project was abandoned, and in contrast, Georgia where it was successfully adopted [8].

The issues of multiple sales, unofficial charges, lack of transparency, bureaucratic hurdles are some of the challenges present in the land management systems in the developing countries [9]. In Pakistan, land record data and management pose significant challenges, and only one province, Punjab digitizing their records [2]. Other provinces still rely on paper-based registries managed by local land administrators termed as patwaris [10], [11]. Punjab created the "Punjab Land Record Management Information System" for simplified management. However, security concerns and infrastructure limitations persist, leaving property records vulnerable to inconsistent and manipulated data [10]. The computerization of land records has brought some problems for the farmers such as lack of proper information, monitoring system, and trained staff [12]. The Ease of Doing Business rank for

Pakistan was 108, whereas for property registration, Pakistan ranks at 151 out of 190 countries [13], [14].

By adopting a blockchain-based land registration system, a developing country can have many benefits, such as, increased liquidity, lower risk, and reduced costs, making property investment more attractive. This can foster economic activity as incontestable land titles allow for investments through mortgages, industrial, and agricultural loans. The findings underscore the negative role that corruption in land records plays in terms of country's development and growth [15].

The focus of this paper is to demonstrate the use of blockchain technology to overcome the challenges in land registry management for developing countries by offering improved efficiency, trust, and accuracy in land ownership transactions. We have assumed land registry processes and issues similar to Pakistan, that are commonly found in the Global South countries.

Rest of this paper is structured as follows: The background information is provided in Section II. Section III covers the related work. Land record management is described in Section IV. Implementation and results are provided in Section V, and the conclusion is provided in Section VI.

II. BACKGROUND

A. *Blockchain Technology*

Satoshi Nakamoto is credited with the refined blockchain design by conceptualizing distributed blockchains [3]. Blockchain has evolved to include networking, mathematical principles, cryptography, and distributed consensus.

Blockchain involves a peer-to-peer distributed ledger system with each participating node maintaining an identical replica, with transaction records, aggregated as "blocks" as shown in Fig. 1. Each block holds a unique identifier, or cryptographic hash, along with the previous block's timestamp and transactional data. The hash is irreversible and cannot be used to extract the data and irrespective of the input data length, the hash length stays the same, e.g., SHA256 hash code encodes to 256 bits [16]. Due to this, any changes to a stored block are immediately noticeable, ensuring security and immutability.

Each transaction within the blockchain is verified through the owner's digital signature, guaranteeing authenticity, and protection against tampering. As a result, the data stored in a digital ledger remains impervious and transparent. Although anyone can observe the stored data, modifying or tampering the data is difficult, necessitating the consent of the majority of network nodes. Consequently, it proves to be an ideal system for registering and managing critical data, such as financial transactions, personal identities, and other sensitive information. However, unlike a database allowing Create, Read, Update, Delete (CRUD) operations, a blockchain only allows create and read, and no data updates or deletes are allowed.

B. *Types of Blockchain*

A blockchain can be classified based on the type of access permitted as shown in Fig. 2. In a permissionless blockchain, there are no restrictions on participation or access, allowing anyone to access and engage with the blockchain [4]. This particular type of blockchain is also characterized by its decentralized nature, devoid of a central authority governing

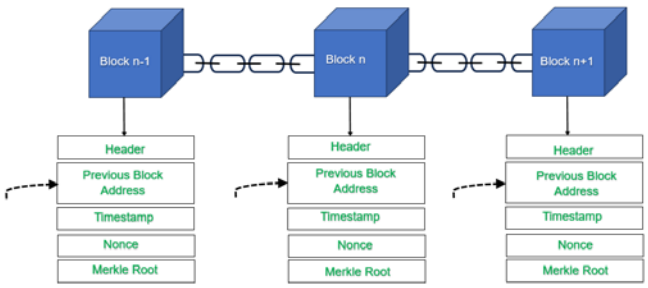

Fig. 1. Visual representation of components of a blockchain.

its operations [3]. A permissioned blockchain restricts access solely to authorized users who possess the privilege to utilize the network and retrieve stored information [4]. Such blockchains find application in environments prioritizing high-level security, where a single organization typically retains control and exercises centralized governance over the system [3]. The hybrid blockchain melds together public and private elements, encompass both public and private data and facilitating transactions of both nature. This form of blockchain finds application in scenarios where certain information necessitates confidentiality, while other information requires public visibility. In a consortium blockchain, a collection of organizations or entities takes charge of overseeing a permissioned blockchain. This type of blockchain operates under the guidance and control of a specific group, ensuring that the responsibilities for maintaining the blockchain are shared among the participating organizations.

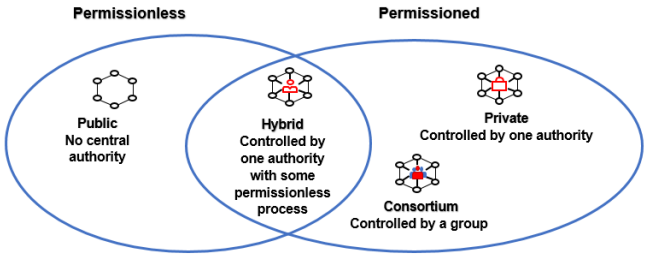

Fig. 2. Types of Blockchain.

C. *Smart Contracts*

The application of smart contracts in the land registry plays a vital role in validating the effectiveness of blockchain technology. By leveraging smart contracts, purchasers can have confidence in the authenticity and uniqueness of the land being acquired, while sellers can provide proof of their lawful ownership, minimizing the likelihood of future disputes [17].

Integrating smart contracts simplifies the process of land titling by automating record updates, eliminating the need for third-party intermediaries, and reducing the potential for errors. This automated approach enhances the speed and transparency of the entire process, as involved parties can swiftly make informed decisions when they have timely access to all pertinent information.

The utilization of blockchain and smart contracts fosters trust among parties by enabling transactions through transparent contracts, thereby enhancing business efficiency

and organization. This technology also fortifies data security and verifies the integrity of land records, mitigating the risk of fraudulent activities. Overall, employing blockchain technology and smart contracts in the land registry holds the potential to increase transparency, curtail expenses, and augment liquidity within the property market. By embracing this technology, the overall land registration process can be optimized to become more efficient, secure, and dependable.

III. Related Work

An Ethereum based hybrid blockchain framework for land registration was proposed for ensuring decentralization and improving the security of the land registry system [18]. It was shown that through the adoption of a decentralized system, all the involved parties in a property transaction, that is, the agent, buyer, seller and the bank can be more secure and safe against any data loss [1], [5]. The blockchain utilization for land registry system was studied and it was suggested that based on the scale and content of land registers, these could be divided according to the administrative units into a new blockchain, as a sidechain to the parent blockchain [4]. A study to determine the role of blockchain technologies for reducing the real estate transaction delays found that the main reason for delays were lack of standardized, trusted, and single source of property information [19].

Smart contracts are self-executing agreements that can be encoded on a blockchain, providing a secure, transparent, and decentralized way to automate transactions and business processes [20]. However, for a wider adoption, the use of smart contracts for government processes should be changeable after deployment, to meet the change in the business rules [21].

A land registry blockchain network of 12 nodes was proposed using Proof-of-Work. With 200 transactions, the results showed a 99% reduction compared to the manual process [6]. The main objective of the study was to ease record management process and to make the transactions secure against cyber-attacks [6]. A prototype automated Land Records Management System (BLRS) using Ethereum and Solidity was proposed comprising of five stages [22]. The authors provided a security and privacy analysis for the proposed system [22]. A framework for land registry system proposed the use of two modules, land registry and verification modules, and used Ethereum blockchain with Amazon Web Services (AWS) for private and public key management [23].

A land titling system for India was aimed at providing authentic rights of ownership, and tamper-proofing the land titles [24]. The proposed system, through smart contracts, could address many of the challenges such as, a foolproof guarantee regarding the property ownership [24]. A blockchain based land registry system was proposed for Ghana's dual land tenure system and it was concluded that this could also be applicable to other sub-Saharan African countries [9]. A land record management system was proposed for Pakistan based on Hyperledger Fabric Framework, identifying the system stakeholders and their roles in the process, together with the workflow [25]. A conceptual framework was proposed for Punjab Land Record Authority (PLRA) using Ethereum and Solidity, and the system was validated with the stakeholders through demonstrations, semi-structured interviews, and surveys obtaining positive feedback [2].

IV. Land Record Management

A. Management of Land Record in Pakistan

In Pakistan, the traditional method of preserving land record data entails the upkeep of physical registers or the utilization of centralized servers managed by a designated individual known as a patwari. Despite the government's initiatives to digitize land records, there remains a substantial gap to bridge before a comprehensive shift to a digital system can be realized. The existing reliance on centralized servers presents various risks, including vulnerability to hacking, environmental hazards, and a single point of failure. Furthermore, entrusting the supervision and administration of the entire system to a single person raises apprehensions regarding potential data tampering or forgery.

A review of the process for the land record creation and administration is provided [11]. Land registration processes play a crucial role in documenting information pertaining to land transactions, providing an official and easily accessible record system for individuals seeking information about specific parcels of land. Such processes typically involve government oversight and the implementation of regulations to define ownership rights and uphold the accuracy of recorded information.

The manual process of land registration consists of six steps and can take up to two months. The rate of stamp duty is also a high cost to consider when registering deeds, which varies from province to province. The land administration process for KP province was investigated, finding that most of the land disputes were related to a lack of access to timely and correct information [11]. It was similarly concluded that although computerization of land records in Punjab province has increased access, still the distance involved to the centres is a major problem for land holders [26]. Land record data storage system relying on a centralized server encounters a range of issues, including the potential loss of data due to natural calamities and the possibility of malicious actors manipulating the available information.

The process of digitization aims to convert paper-based land records into a digital format stored in a centralized system [2]. This transformative process seeks to reduce errors in record-keeping and minimize land disputes, as the creation of counterfeit documents would become more challenging and hold little legal weight within a digital framework. However, substantial progress is still required to ensure the precision and security of the digitized data.

B. Land Registry Using Blockchain Technology

Integrating a land registry system based on blockchain technology effectively solves several major issues encountered in traditional land record systems, including data collection and storage, data confidentiality, and the verification of ownership details. A blockchain-based system also allows for the inclusion of information related to the origin of funds utilized in land transactions, encompasses details of the involved financial institutions and insurance providers.

In addition to the ownership and transaction details, the quantity of land purchased by an individual or enterprise can also be recorded in the blockchain. The system also allows for representation of previous transaction details and information about financial institutions, while maintaining the privacy and protection of collected data.

One of the main advantages of a blockchain-based land registry system is fault tolerance against data loss. Additionally, the system can easily reference all transactions previously made for a property, eliminating the need for tedious record keeping and ensuring transparency in land ownership.

V. Implementation and Results

In the proposed land registry network, different devices like cellphones, laptops, and PCs function as network nodes. Each node has public and private keys that are created using MetaMask, which is a popular Ethereum wallet and browser extension.

When nodes join the network, they receive roles according to their authority and purpose in the land registry system. For example, property owners, government officials, and legal entities involved in land ownership would have different permissions specific to their roles. The access control restricts the authorized individuals to access and modify only the allowed land ownership data.

We also created a website to make it easier for the system users to interact with the land registry system. The website's design and features are tailored according to the user's role and permissions. For example, property owners can effortlessly view and handle their land records, while government officials can carry out administrative duties, such as, property registration and verification.

To simplify the land registry process, we implemented smart contracts in the Solidity language. These contracts automate transactions related to land, removing the need for middlemen and making the process more efficient.

A. System Design

The system diagram is shown in Fig. 3. The diagram shows the three implemented interfaces for the admin, inspector, and a user role. For each role, the corresponding application use case are also illustrated.

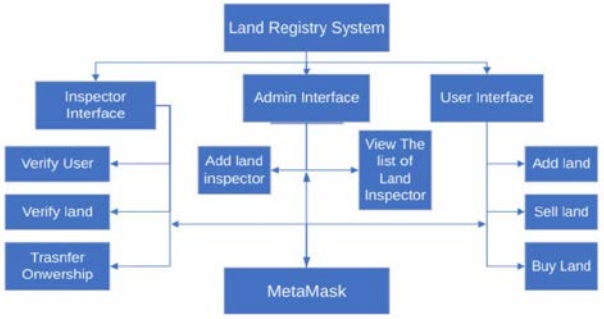

Fig. 3. Functional Block Diagram for the Decentralized Application (DApp).

B. Development Environment

The development environment comprised Solidity, Hardhat, Ether.js, React.js, Next.js, Chakra UI, Alchemy, and Mapbox Application Programming Interface (API).

1) Solidity: Solidity is the programming language used for writing smart contracts on the Ethereum blockchain. We used the Solidity compiler (solc) but another option could be Remix Integrated Development Environment (IDE).

2) Hardhat: It is a widely used development environment for Ethereum smart contracts that offers a range of tools facilitating the compilation, testing, and deployment of smart contracts.

3) Ethers.js: Ethers.js is a JavaScript library specifically designed for Ethereum application development and provides features for account management, contract deployment, and transaction handling, besides other features.

4) React.js and Next.js: React.js is a widely used JavaScript library for constructing user interfaces, and it can be paired with Next.js, a framework that streamlines the development of React.js applications.

5) Chakra UI: Chakra UI is a library of UI components, designed specifically for React.js applications.

6) Alchemy: Alchemy serves as a remote node provider, enabling a connection with the Ethereum network and to remotely engage with smart contracts.

7) Wallet: we used MetaMask to create a cryptocurrency wallet, required for decentralized applications (DApps).

8) Mapbox API: Mapbox API is a powerful mapping platform that provides APIs for embedding maps and location-based services in DApps. An account is required to obtain the API access token.

C. Smart Contract

The development steps for smart contracts using Solidity include design choices, defining the business logic, and implementing the desired functionalities. We created individual contracts dedicated to specific functionalities. For example, a contract solely for facilitating land ownership transfers, and another for querying land information. By adopting this strategy, we aim to promote the reliability, confidentiality, and effectiveness of our land registry operations. For example, the smart contract for registering the land enables users to enroll newly acquired land by submitting the required particulars, such as the land identification, owner's name, and geographical coordinates. This data was safely stored within the contract's designated data framework.

We deployed the smart contracts on the Matic Testnet. The testnet deployment allows confirming the correct functioning of the contracts before launching these on the mainnet.

We defined a *LandRegistry* contract that contains land structure representing the details of a particular land. The *registerLand* function is responsible for adding a new land to the registry, while *transferOwnership* facilitates the transfer of land ownership to a new owner. Additionally, the *getLandDetails* function allows for the retrieval of specific land details.

D. Consensus Algorithm-Proof of Stake

Proof of Stake (PoS) represents a group of agreement algorithms used in open blockchains, relying on a validator's financial interest in the network. The consensus algorithm that allows current validators to create and agree on new blocks is the crucial aspect. In chain-based Proof of Stake, the algorithm randomly selects a validator during each time slot (e.g., every 10 seconds) to create a single block.

E. User Interface and Application Roles

The DApp's home page is shown in Fig. 4. The three buttons for each of the user roles are provided to log in as an admin, land inspector, or a user (buyer/seller). Any of these options, displays a popup to facilitate the wallet connection, also possible through a mobile device.

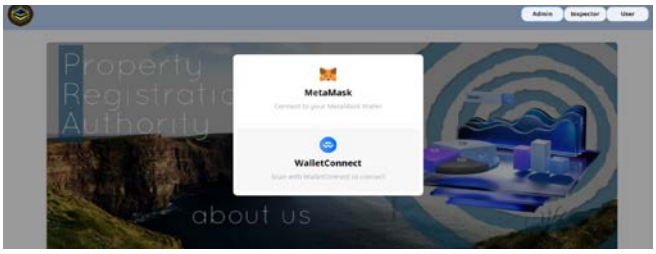

Fig. 4. Landing page of the DApp.

We implemented the functionality and interfaces to all application features for the three system roles but due to space limitations describe only few of the important features in this paper.

1) Admin: When the Admin button is clicked, it opens the Admin dashboard Home page, shown in Fig. 5. The navigation pane has options for Home, Add Inspector, View the List, Change Admin, and Search Details.

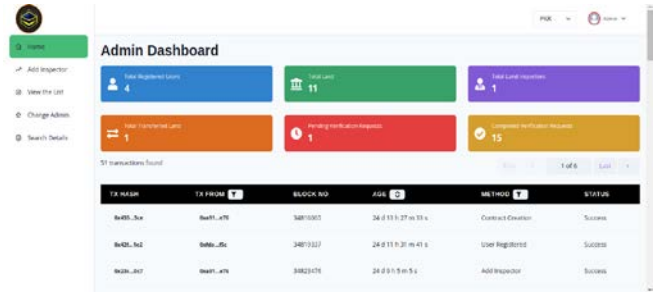

Fig. 5. Admin dashboard.

With the search feature, an Admin can easily look up specific information, for example, for the land information, the land ID can be used for details, as shown in Fig. 6.

Fig. 6. Registered land details.

2) Inspector: The Inspector dashboard has navigation pane options for Verify User, Verify Land, and Transfer Ownership.

The Verify Land function empowers inspectors to confirm the legitimacy and ownership of land or property records in the DApp. Inspectors can examine the details, cross-reference these with external sources, if needed, and indicate the land's verification status within the DApp as shown in Fig. 7.

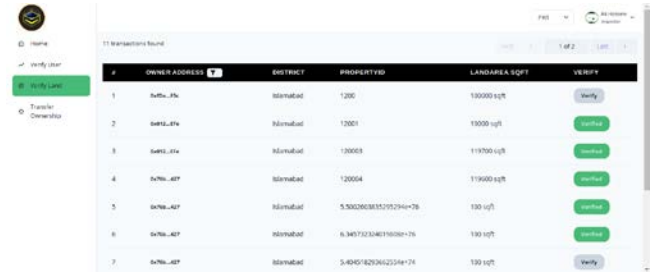

Fig. 7. Verify land interface.

3) User: When the User button is clicked by a registered buyer or seller, they will get access to the features within the DApp. However, if a user is not registered, they will be directed to the registration page. The navigation pane has options for Land Market, My Lands, Send Requests, and Register Land.

The Register Land functionality allows users to register their land using the DApp, as shown in Fig. 8. Please note that although the complete steps are not shown here but this entry requires to be authenticated by the Inspector before the land is registered.

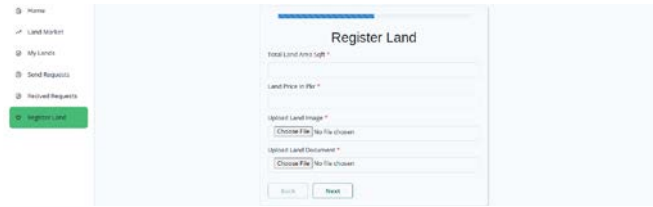

Fig. 8. Register Land interface.

F. Unit Testing with Hardhat

We used the Hardhat framework in combination with the Chai assertion library to verify the smart contracts and their collaboration with the DApp's frontend.

We created unit tests for the smart contracts within the DApp. Unit tests validate the functionality of individual functions or methods within the codebase. By implementing these unit tests, we proactively identified potential flaws and guaranteed the intended behavior of the smart contracts.

G. Continuous Integration and Deployment

By default, Vercel has a feature that triggers automatic deployments whenever there are new code changes pushed to the connected GitHub repository. This means that when updated code is pushed to the designated branch, Vercel will autonomously reconstruct and redeploy our DApp frontend.

By adhering to these steps, we can deploy our DApp frontend directly from the GitHub repository to Vercel without the necessity of any manual intervention. Thus, with the Vercel's continuous deployment capability, our DApp will consistently reflect the most recent code updates.

H. Use Cases and Limitations

The users can register for an Ethereum account and complete a registration form. The administrator and land inspector can then validate the user credentials and the property details. After the verification process is complete,

the user gains the ability to sell the land. Only the land inspector can modify details such as price, dimensions, or proxy ownership. A buyer can submit an offer for the land available for sale for the seller's consideration. The seller has the choice to accept or decline the offer. Upon acceptance, the buyer pays the agreed amount. After receiving payment, the land inspector oversees the transfer of ownership to the new buyer. Notably, the inspector captures images of the buyer, seller, and witnesses during the transfer. In summary, the Land Registry DApp project strives to establish a transparent and efficient land registry system that eliminates fraud, saves time, and enhances security for landowners.

The generalizability of the findings may be limited due to the specific context of the land registry being studied. The research findings may primarily apply to similar land registry systems or blockchain implementations. Technical challenges in implementing the blockchain-based DApp, such as scalability or interoperability issues, may pose constraints on the research process and the evaluation of the DApp's performance.

VI. Conclusion

The proposed Land Registry Decentralized Application (DApp) can help to tackle the land-related issues in the developing countries, including fraud, inefficiency, and time-consuming procedures. The digitalization of the paper-based land records can help to take the next step of incorporating the blockchain technology in the land management. The incorporation of blockchain technology though needs to be supported at the country level for its success, and exploiting its benefits for economic development.

As future work, we would explore the use of Artificial Intelligence together with the blockchain system for ensuring the system security. We would also consider introducing a governance system, enabling decentralized decision-making for system changes and updates. This could involve a token-based voting setup where stakeholders can propose and vote on system modifications. We will also investigate the techniques to resolve scalability and interoperability issues.

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