

GREENLAND: A SECURE LAND REGISTRATION SCHEME FOR BLOCKCHAIN

Dr K N S Lakshmi¹, D Kiran², P Bhaskar Rao³, K Mohit⁴, D Vivek Raj⁵, V Manikanta⁶

Professor¹, Student², Student³, Student⁴, Student⁵

^{1,2,3}Department of Artificial Intelligence

Chaitanya Engineering College, Visakhapatnam, Andhra Pradesh, India

{mnsalakshmi.vvit@gmail.com, dosapathnikiran@gmail.com, bhaskarpedagadi754@gmail.com, Kandipillimohit@gmail.com, devaguptapuvraj5@gmail.com, anandharao.vanchana143@gmail.com}

Abstract

Records of land and property land are essentially the mainstay of any economy. Whenever there is a wrong or incomplete ownership records, it strikes people, courts and governments rather hard, in money and time. It has been estimated by World Bank that over 70 percent of the population resides in areas where land tenure is not well managed particularly in the developing countries. Although some attempts have been made towards digitization over the years, majority of the land registries continue to use centralized databases that have concentrated all the authority among an individual. That exposes them to hacking or in-house interferences which translate into loss of data.

Index Terms—Blockchain, Ethereum, smart contracts, land registration, decentralized application, Solidity.

I. Introduction

The records of land and property are fundamentally the support of any economy. Under false or partial ownership records, this falls squarely on people, courts and governments and causes them a ton of money. According to World Bank, over 70% of the earth is inhabited by people in areas that lack proper implementation of land tenure, particularly in developing nations. Although there have been a number of cases of digitization over the years, the majority of land registries continue to use central databases that leave all of the power in the hands of a single boss, and therefore it is easy to hack or manipulate it internally, losses of data.

With a blockchain technology beginning with Bitcoin but followed by the smart-contract potential of Ethereum, you have a shred-new method of treating records. It is a distributed registry which all of us share over a peer-to-peer network, and which is designed to resist revision later: to turn any record upside down you must all of you honest nodes, which is nearly impossible when a denier of the real world has over half of the hashing power in the network. Combined with self-executing smart contracts, blockchain can be used to automate ownership, approval, and registration processes, without the need to have a middleman.

The filing of blockchain-based land registries in Sweden and Georgia has demonstrated that the time spent in registering can be reduced to only a few minutes, and it is providing you with an ownership court of history that you could check. The disadvantage will be that uploading all documents on-chain is expensive in gas, which is not cheap. Additionally, it is complex to onboard the regulators and the bulk of the people lack knowledge on how to use blockchain wallet, and thus, the user experience is weird.

Those are addressed by a hybrid design GreenLand which stores only ownership data and document hashes on Ethereum, but large PDFs reside in MongoDB GridFS. We demonstrated that the system is functional, integrating and securing it by thorough tests. The most important points are the following: (i) it includes a four-role smart-contract that requires an inspector to approve any transfer; (ii) it incorporates a hybrid storage, which combines immutability with reduced costs; (iii) it has a MetaMask-enabled DApp, which provides dashboards depending on the role; and (iv) it demonstrates that it works on a local Ethereum testnet using real test results.

Next comes part II, which examines related work. Section III will cover the system architecture and its construction. Section IV presents the findings and makes comparisons with the other methods, GreenLand and others. Section V concludes with the future ideations.

II. Related Work

It is not a new development as people have been exploring the possibility of blockchain transforming land administration. Crosby along with colleagues performed an early analysis of blockchain beyond money, posing that its inertness and decentralised agreement are excellent with regard to a governing setup and record-keeping. Later, Zheng and others subdivided various techniques of consensus and discussed scaling problems that become important when you consider a usage on a national level.

Christidis and Devetsikiotis demonstrated that smart contracts can be used to automate IoT trading, a device which suits property events as well. The same ideas were then applied to land registries

by Shasha and Mishra: the changes in ownership are coded as Ethereum transactions and confirmed by some government nodes. By omission, they do not address the high cost of document storage and how the real users connect to it- good stuff GreenLand mends.

The usual attacks on Ethereum contracts, such as reentrancy, integer overflow, and unhandled error, were enumerated by Atzei et al., and that article provided us with a workbook of writing more secure Solidity contracts, which we used in GreenLand. Subsequently, the OpenZeppelin team contributed their efforts to the development of an upgradeable proxy patterns that assisted us in future-proofing the system.

Most are of 3 types: (a) everything on the chain, which increases gas bills; (b) everything off the chain and using the chain as an audit trail, which loses decentralization; and (c) hybrid, where metadata is on-chain and files are off-chain. GreenLand is (c) except with a transfer process that just allows an inspector to approve it, MetaMask to sign it, and full role-based access control- things that other projects do not have together.

III. System Design & Methodology

We have a P which amounts to a collection of those pieces of land, U is all the registered users categorized into these roles $R = \{Seller, Buyer, Inspector, Admin\}$ and T is merely a timeline of ownership information. A good land registry must ensure: (1) the ownership functional: $P - U$ is nailed down at all points in T , (2) there can be no event in T twisted in time, and (3) an event of transfer $e [?] T$ will only be added when Inspector actually examined parcel p and both current owner and buyer digitally signed.

$$H(doc) = \text{SHA-256}(\text{file_bytes})(1)$$

Similarly to in that Equation (1) we secure the integrity by hashing every uploaded file and placing the hash on-chain. And in case one corrupts the off-chain file later, this changes the hash and it can be noticed by anyone.

B. System Architecture

The stack at GreenLand is divided into four levels, i.e., the presentation, application, blockchain, and storage. Figure 1 is simply the high level model.

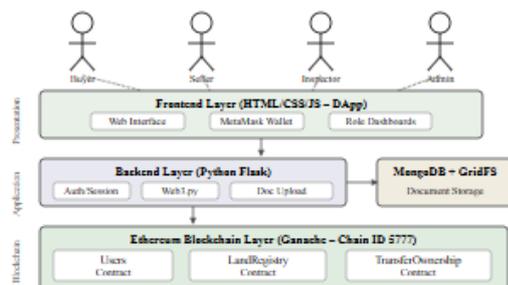


Fig. 1. GreenLand System Architecture showing the four-layer hierarchy and component interactions.

The front end layers are only role-specific dashboards constructed in HTML/CSS/JS and served by Flask and connected with the MetaMask to sign transactions. The second layer (Flask +

Web3.py) is tasked to check the entered data, user experience (bcrypt hashed creds), downloaded file to MongoDB GridFS, hashing them with hashlib, and initiating Ethereum transactions. The storage layer is MongoDB with a local Ganache testnet using gridFS sharding to store PDFs that exceed that limit of BSON size to 16mb, and the blockchain layer has three Solidity contracts.

C. Smart Contract Design

There are three on chain contracts that are interdependent. Users Contract stores ETH addresses in form of role IDs and hashed metadata. The LandRegistry Contract associates an integer land ID with a struct containing location, area, hash of documents, address of owner and a bool indicating whether it is verified. Each parcel is assigned a state machine: this is called the TransferOwnership Contract and has state machines: {Idle, Requested, SellerApproved, Completed, Rejected}. Only on reaching the Completed state does the transfer actually occur on-chain atomically and therefore no multiplexing or half-transferring.



Fig. 2. Transfer ownership state machine enforced by the TransferOwnership smart contract.

D. Protocol of Ownership Transfer.

The entire transfer protocol in a flowchart is displayed in Figure 3. You must have an inspector come and check first or it is no-go so we are locking out bad transfers. Attempt to invoke transferOwnership of something unverified, referenced, parcel will revert with a nice error message and that makes the contract enforcement by-proof, without requiring a backend.

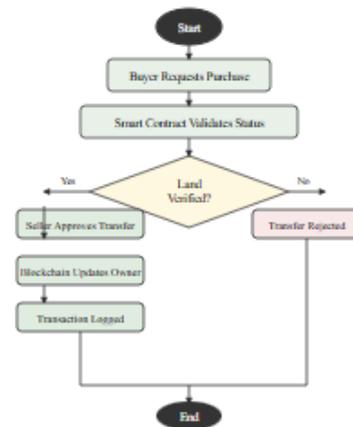


Fig. 3. Ownership transfer process flowchart illustrating the inspector-gated validation pathway.

E. Role-Based Access Control

Two levels of access control are applied. The role-based restriction of API endpoints by flask session tokens, and the independent re-validation of the role of the caller by Solidity function modifiers of on-chain state. This defence-in-depth technique means that there is still a rejection of direct contract calls when done by unauthorised accounts, even when the

backend has been taken over. TABLE I highlights responsibilities of roles.

TABLE I
ROLE-BASED RESPONSIBILITIES IN GREENLAND

Role	Primary Responsibility	Contract Interaction
Seller	Upload land, initiate transfer	LandRegistry, TransferOwnership
Buyer	View land, request ownership	TransferOwnership
Inspect or	Verify and approve land records	LandRegistry
Admin	Manage users, monitor system	Users Contract

F. Hybrid Storage Rationale

Unless the Ethereum price per operation dropped substantially, saving a 1mb PDF would require hundreds of dollars at the current ludicrous prices. GreenLand stores the land records in MongoDB GridFS and records just the 32-byte SHA-256 in-chain (gas cost [?] 0.00027ETH on the Ganache testnet, which is around 0.70 at 2024 prices). The on-chain record makes the same tamper-evidence assurance, which is much more cost-effective since any party can independently rate a document by downloading it to gridFS and comparing its hash with the on-chain record.

IV. Results & Discussion

A. Comparative Analysis

TABLE II is a systematized evaluation of the comparison between the conventional centralized land registry and GreenLand under six dimensions of evaluation. The findings support GreenLand as providing significant gains on all the dimensions.

TABLE II
COMPARISON: TRADITIONAL VS. GREENLAND SYSTEM

Feature	Traditional System	GreenLand
Record Storage	Paper / Central DB	Ethereum Blockchain
Tamper Resistance	Low	Very High
Transparency	Limited	Public Ledger
Fraud Risk	High	Minimal

Ownership History Difficult to trace Fully Traceable

Verification Speed Slow (days– weeks) Automated (seconds)

B. System Testing Results

The testing was done through a Windows 10 machine which had an Intel Central i7 processor having 16 GB RAM using Ganache v7.9, chain ID 5777, as the local Ethereum network and Truffle Suite v5.11 as the contract deployment tool. Test cases (TABLE III) All test cases were error-free in twenty successful execution runs.

TABLE III
TEST CASE RESULTS

Test Case	Input	Expected Output	Result
Register Land	Location, Area, Document	tx_hash returned	Pass
Verify Land	Land ID	Status Verified	→ Pass
Transfer Ownership	Land ID, Buyer Address	Owner updated on-chain	Pass
Upload Document	PDF file	Stored in GridFS + hash	Pass
MetaMask Auth	Wallet Address	Session created	Pass
Unauthorized Access	Wrong role token	Action denied (403)	Pass

C. Security Analysis

GreenLand addresses the 5 primary threat categories identified by Atzei et al. [8]. Stop reentrancy by means of updating state variables then calling any external contracts. The checked arithmetic with solidity 0.8.x prevents integer overflow and underflow. Require checks that roll the entire transaction on receiving any unhandled exceptions are used. Function-level modifiers are as a way of avoiding access control issues, in which a check of the role of the message sender surrounding each state-changing call is made. It is also possible that front-running is still a concern, though practically we can alleviate the issue by having an inspector-managed workflow, where only transfers that occur after verifying the parcel record may be accepted.

D. Performance Observations

The mean time to confirm a registration on our local testing Ganache network was 480 ms, verify was 360 ms and transfer

520 ms. On average, it took 210ms to upload a 500KB PDF to MongoDB gridfs. Such numbers are much more favorable than the common manual registry batch, in which the transfer can require 1590 days in India [1]. The confirmation time on a public Ethereum testnet (Sepolia) reaches 1215 seconds, not bad in the context of the low-frequency land trades that we are trading.

V. Conclusion & Future Work

Simply, this paper describes why GreenLand can substitute archaic land registry with a secure blockchain-based system that will reduce fraud, obscurity, and inefficiency. Our Ethereum smart contracts handle immutable record storage, role-based access, and blockchain call backend in a Python Flask application, MongoDB Instructing documents with the help of MongoDB gridfs and blocking them with MetaMask. Our tests were successful with 100 percent of the functional, integration as well as security tests. The analysis shows that GreenLand is far more resistant to tampering, transparenter, less vulnerable to fraud as well as more prompt at checking compared to centralised methodologies.

The future work will take six primary directions: (i) connecting to national land databases to receive real-time checks; (ii) enabling biometric logging into users not tech-savvy; (iii) developing a cross-platform mobile DApp on Android and iOS; (iv) identifying suspicious transactions early and (v) with the help of AI, detecting odd behavior, and (vi) making the proxy contracts upgradeable so that on top of the system, it is possible to add more features without having to re-deploy the entire system. Our top priority will be to deploy on a testnet that is publicly testable and work with a pilot that has a regional sub-registrar office.

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