Land Record Management using Hyperledger Fabric and IPFS

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***Abstract*—Status quo, the process of maintaining land ownership records employed by many countries is archaic, providing scope for fraudulence, tampering and/or misrepresentation of data, with little to no accountability for ensuring the authenticity of the managed records. This inefficiency and lack of transparency in the system can heavily exploited by the malicious middlemen with questionable intent, entrusted with the task of maintaining the records. The paper aims at introducing transparency, especially in the realm of land acquisition and ownership record management, by ensuring that each transaction is validated by all involved parties. It removes the scope for fraudulence by creating an immutable history of records, which is permanently linked to the system, thereby streamlining documentation and record-keeping. A peer-to-peer tamper-proof and forge-proof network is leveraged for this purpose, using a permissioned Blockchain such as Hyperledger Fabric. The system is interfaced with Interplanetary File System for secure documentation record management.**

***Keywords*—Blockchain, Hyperledger Fabric, IPFS, Passport, peer-to-peer, decentralized, land record management.**

I. Introduction

Traditionally in India, land was majorly owned by the landlords who had permanent property rights. These landlords collected rent from the land users such as farmers, and paid a fixed land revenue to the Government [1] [3]. The responsibility for land administration was transferred to the states later. All the records were obtained and managed manually by respective revenue departments. This obsolete system of land record management was very recently upgraded to a computerized method, but the actual documents that determine the ownership of land are still maintained offline on paper. Furthermore, those documents are scattered across different Government and non-Government offices, making it easy for fudged records to go unnoticed.

Systems employed for digitizing land records are largely centralized, with a single computing, storage, processing unit, making it very vulnerable to malicious attacks, as there is one primary point of vulnerability in the set-up - the centralized system itself. Even the server-client architecture, which is deemed to be very sought-after, is a distributed architecture only with respect to hardware specifications. At an application level, even cloud systems are centralized. Hence, the need for a decentralized system which distributes the risk of an attack over all the involved parties, at the same time not compromising on security, is more apparent.

A. The Blockchain

Blockchain is a Distributed Ledger which is peer-to-peer, realized by consensus, to make business processes secure and transparent [2]. Consensus algorithm is defined in the Smart Contracts of the Blockchain [2], i.e., programs that automatically execute predefined actions when conditions in the system are satisfied. In this paper, the consensus algorithm is set by the admin of the land acquisition management network. The immutable history of records maintained in the Distributed Ledger define data authenticity and security in the system.

B. A peer-to-peer network

Computers connected to each other without a server essentially constitute a peer-to-peer network, thereby increasing the security since there is no single point of vulnerability. Transactions are admitted into a block only if all the peers agree to it, and all peers have access to all the records of transactions performed in the network. In this paper, landowners are given reading access and Government officials responsible for the maintenance of land records are given, both read and write access to the Blockchain [2].

In the following sections of the paper, discussions on related work in the realm of land record management and Blockchain for record-keeping shall be briefly explored in Section II to understand the shortcomings of the current systems. Section III on proposed solution will explain the methodology employed in the paper to address the research gap. Section IV on underlying technology and architecture will explain about various solutions leveraged to serve the proposed solution. Section V on the implementation provides a demonstration of the proposed solution, followed by Section VI on enhancements for efficiency, where measures to increase the productivity of the network will be discussed and Section VII compares the proposed solution with existing systems. The paper concludes with VIII, IX future scope and X acknowledgement.

II. Related Work

There has been considerable focus by various Government offices to digitize information about their citizens for easy and quick access of information.

Digital India Land Record Modernisation Programme (DILRMP) [4] [5], an initiative by the Government of India, focuses on digitizing land records. A separate portal is available for citizens to access electronic certificates of land records. This cuts down the time for accessing records as it reduces the interaction between the citizen and the Government employees. This curtails significant number of fraudulent transactions and acts as evidence in case of disputes. Likewise, Land Records Mission Mode Project (MMP) [6] is a program under National e-Governance Plan (NeGP) which aims to accelerate easy maintenance and updation of land records by keeping track of mutation cases. It also ideates to devise strategies for infrastructural and environmental development. While computerization of land records is a step forward, the system architecture is still effectively centralized, which is not ideal in terms of data security. Additionally, land record documents which essentially define ownership of the land are not included in the digitization process and are still maintained offline.

Intelligent Government Scheme Advisor (IGoSA), a proposed e-Governance model by Sabyasachi et al. implements various schemes for the citizens [7]. Their paper highlights the procedure of data gathering. Its initial step is to extract data from various Government Departments, Government servers etc, which is used to analyze existing schemes and display findings over the Internet to different beneficiaries. Based on the evaluation the Government can generate or modify schemes based on the evaluation presented by the system. However, there lies a possibility of data tampering or privacy breach by Government officials. This fuels the lack of transparency in the system.

Tatiana et al. show how the intervention of Blockchain in Government auditing can overcome existing inefficiencies [8]. Initially the Blockchain is analyzed for a specific period, following which, some blocks are sent to the Government Inspectors for inspection. If the blocks are found to be suspicious, the original primary documents are checked by the auditing department for violations. This is followed by an assessment by the inspector, inferences of which are sent to the law regulators for further queries. This model has the scope for being highly secure, resilient since it employs distributed ledger. However, there is dependence on the legitimacy of the assessment of the inspector.

Nour et al., through eGov-DAO have tried to include permissionless Blockchain in systems such as election voting, where transparency and security are of utmost importance [9]. The inclusion of Blockchain into their general model claims to reduce security risks, although it fails to provide a concrete methodology for the implementation of the system.

An experiment by Heng et al. in Chancheng District, seat of Foshan City, China aims to extend the application of Blockchain in e-governance [10]. This provides individuals with a robust platform for record management where it can fetch required details, instead of turning to third-party entities like Government registries. This not only helps the Government devise a transparent system for its citizens, but also accelerates policy implementation.

A. Limitations of related work

While many papers explained how digitization of land records can help in better maintenance of land records, transparency and security is still a concern. Furthermore, many papers discussed using public permissionless Blockchain to decentralize systems which gives open access to all the members of the system without compromising on security. However, for most applications discussed above, transacting parties are known, and procedures for determining identity of users in a permissioned Blockchain setup is tedious on the computational resources of the user's system. In such cases, permissioned Blockchain platforms like Hyperledger Fabric, which employ private membership to the users and have preselected, trusted validators, prove to be more appropriate for the application.

III. Proposed Solution

In many countries, land ownership records are spread across various departments, and are hardly ever comprehensively available in a single location. Furthermore, the onus of checking and acquiring past property ownership records and deals is on the current buyer [1]. Through this paper, we present how this inherent inefficiency in the system can be curbed by bringing all the stakeholders for a piece of land/property on a single peer-to-peer, decentralized network, so that transparency can be established [11] [12]. This single platform maintains a detailed record of every transaction that any property listed on the platform has been involved in. Hence, for this purpose, the paper proposes to use a Blockchain framework called Hyperledger Fabric, one of the Hyperledger projects hosted by The Linux Foundation. Fig. 1 refers to the flow diagram of the proposed solution that brings together different Government and non-Government offices under one application through Blockchain. The central Government is able to view land records pertaining to land of all the state Government offices under the jurisdiction of the central Government. Consequently, each state Government maintains land records that can be accessed and edited by private realty companies to update

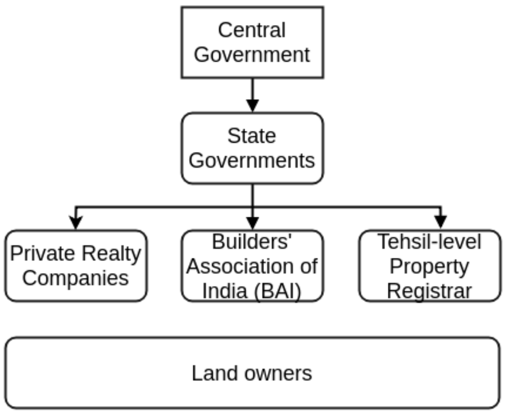

Fig. 1: Flow diagram of proposed solution

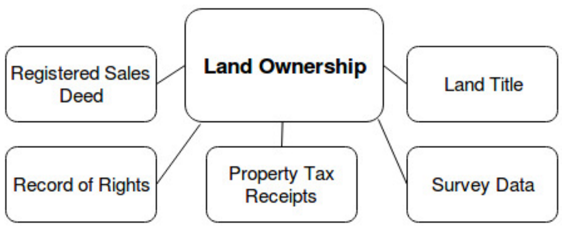

Fig. 2: Representation of documents for establishing land ownership in India

their client information, and by the Builders' Association of India and Tehsil Level Property Registrars of each district in the state. Each landowner gets access to view the details of their respective land, a record of which is maintained by the Blockchain.

In India, land entitlement is confirmed through a number of documents such as [1] [5]:

- The Registered Sale Deed : a record of transaction related to an immovable object such as land, between a buyer and a seller
- Record of Rights : a document containing information related to the property
- Property Tax Receipts : a property tax receipt can aid in finding out the ownership of the land as the rightful owner would have paid taxes for their land.
- Survey Data : Data of the land in the form of maps or 7/12. Water sources in the area, Accessibility to Electricity, Transport services.
- Land Title : A document that determines the ownership of land

Fig. 2 flow diagram visually explains how land ownership is ascertained using various documents.

The paper proposes to make all of these documents easily available to all the stakeholders, on a single platform, by interfacing Hyperledger Fabric Blockchain network with Interplanetary File System (IPFS), a peer-to-peer decentralized distributed file system.

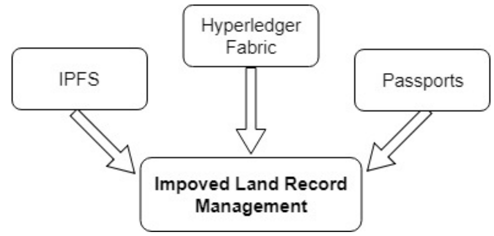

Fig. 3: Interfacing underlying technologies with Fabric to improve land record management

As an extra measure for data security and privacy, the paper proposed to integrate Passports, a secure authorization and authentication middleware and making record-entry makers to log in through their Github accounts before accessing the Blockchain network. Fig. 3 represents how the interfacing of IPFS and Passports with Hyperledger Fabric will hugely improve land acquisition and record management practises in the region and prevent malicious tampering of information that demands utmost confidentiality.

IV. Underlying technology & Architecture

A. Making the choice with Hyperledger Fabric

There are various Blockchain platforms available free of cost. They can be broadly classified as [13]:

- Open-public Blockchains: which are permissionless, like Ethereum. They facilitate parties to transact without verifying their identity.
- Permissioned enterprises Blockchain: which are permissioned, like the various Hyperledger Blockchain frameworks. Only trusted parties, who have allowed each other to be a part of the network, can transact. However, their identity can be abstracted by the network creator.

Open-public Blockchain demands miners to mine the blocks by solving hash. This, however, requires a lot of computational power and resources. This is inconvenient if only known, verified parties, like in this case, will transact with each other always. The act of solving a hash in order to verify their identity becomes redundant. As long as business logic and set conditions stated in the Smart Contract (called Chaincode in Hyperledger Fabric) are satisfied and Consensus Algorithm is not violated, the block can be admitted to the chain. This saves a lot of operational and hardware cost, without compromising on throughput, which is especially important for this application. Additionally, the efficiency of Ethereum Blockchains in terms of number of transactions performed per minute currently is not comparable to that of Hyperledger Fabric [14]. Fabric addresses performance scalability and privacy issues otherwise found in a permissionless mode of operation, by leveraging on a BFT algorithm and superior access management. Its modular architecture of distributed ledger and logic processing increases confidentiality, resilience and flexibility considerably [2] [14].

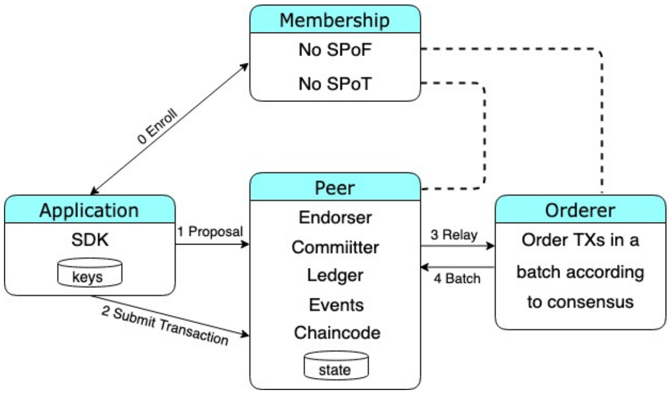

Fig. 4: Flow of transactions and blocks in the system [15]

Therefore, for the reasons discussed above, Hyperledger Fabric was chosen for the implementation of the proposed solution.

B. Peers

Hyperledger Fabric has the following kinds of peers [14]:

- Endorsing Peer: It receives transaction admittance request from the client Application SDK, and grants admittance permission to the SDK if the business logic is satisfied. Therefore, it must hold the Chaincode.
- Ordering Nodes (service) or Orderer: It bunches up a number of transactions approved by the Endorsing Peer into blocks and distributes to the Committing Peer If the system contains only one Orderer, the consensus is known as Solo, otherwise Kafka. The solution uses Kafka consensus algorithm to reduce the risk of network downtime.
- Committing Peer: It may or may not hold the Chaincode. Its task is to admit the blocks sent by the Crderer to the Blockchain.

Application SDK sends a request to the Endorsing peer, which in turn runs the Chaincode to see if it satisfies the business logic. It sends a ”send proposal response back” to the SDK, after checking if all the rules are followed. It sends the original transaction back with a sign, and also a set of W/R, for the client to check if incorrect inference was drawn while checking rules of Chaincode. This allows the SDK to send the transaction to the chain. This transaction is divided into blocks by the Orderer, for all the channels in the network. Appropriate blocks are received by the Committing and Endorsing Peers, who validate each transaction and commit to block [2] [16]. This is illustrated in Fig. 4 The architecture specifically for the proposed solution is described appropriately in Table I.

C. IPFS

IPFS (InterPlanetary File System) is a file storage system which is decentralized, that enables the storage, access and security of files over a distributed file system. A cryptographic hash is created for every file. The files are stored in nodes, whose indexing is done such that each file can be accessed through the node which prevents duplication [17].

Network Component	Use
Application SDK: Admin making a new entry or edit into records (transaction)	Sends request to Endorsing peer, waits for approval
Endorsing Peers: District and city registrars	Runs chaincode to see validity of Application SDK's request
Ordering Nodes: State Government Office	Bunches transaction into blocks and distributes to community peers
Committing Peers: City Municipality	Commits block to the network

TABLE I: Role of system entities in a tabular form

D. Passport

The solution also embeds an additional layer of security in the system by using Passports, and authentication and authorization middleware to log in to the Land Acquisition and Record Management Portal so that users can sign in through their social media accounts, i.e., OAuth providers such as Twitter or Facebook or email accounts, for ease of authentication. Services that expose an API, more often than not, need token-based credentials to secure access. Without creating dependencies, applications can choose from the strategies, i.e., authentication mechanisms which are packaged as individual modules, to be deployed in the system. This is highly beneficial since it provides an encapsulation for all the complexities that are involved in user authentication [18].

V. Implementation

The proposed solution talks about introducing transparency in the realm of land record-keeping, such that all the transactions or alterations made to the records are accessible to every stakeholder. Transactions satisfying set conditions defined in the Chaincode can only be admitted in the Blockchain. This ensures that only legitimate actions pertaining to the mutation of land-record can be performed. By introducing Blockchain into the solution, it is ensured that each change that occurs in land records is being logged into the block-code and the landowners, the Government officials and other stakeholders can see if any changes that have not received approval and/or acknowledgment is made to the record. For security reasons, the landowners will have no editing rights, and edits in the records can be made only by Government officials. However, landowners will be able to see if any transaction involving their owned property has been performed.

For ease of demonstration, the solution is implemented on Hyperledger Composer. Coding in Hyperledger Fabric requires users to write the algorithm of the consensus, i.e. Chaincode in Go or Node.JS, in order to permit the admittance of each transaction into the Blockchain [2]. Hyperledger Composer is an abstraction for Hyperledger Fabric, which provides modularity in terms of writing the business logic, and also provides support for various integrations such as REST-API for the back-end interface of the business network, Angular for

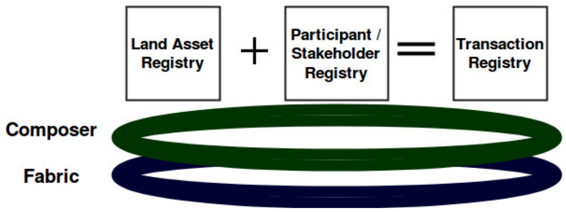

Fig. 5: Representation of Assets, Participants, Transactions defined in Composer, running on Fabric

the front-end interface of the business network, and Passport support for an even secure login process [19]. Fig. 5 provides a representation of how Assets, Participants and Transactions are defined in Hyperledger Composer. For the solution, their definitions are described in Table II.

Composer Entity	System Entity
Assets	Land records: land and owner credentials, area, land ownership related papers secured through IPFS, an indicator to illustrate if the asset (land) is for sale
Participants	Stakeholders: Government offices, non-Government offices, land-owners
Transactions	Sale of land if it is listed for sale, updation of records, new land property listing

TABLE II: Definition of Composer entities

Hyperledger Composer is used to provide business network definition using the following primary components [19]:

- Model file (.cto) : This defines entities of the network such as the Assets, Transaction/s, Events and Participants for the business network.
- Script file (.js) : Transaction Functions thereby defining the business logic are stated in this file. The Function first checks if the Asset is eligible for exchange between two Participants, by checking if it is listed for sale, following which, it qualifies the Transaction entry with Buyer, Seller and Asset credentials, and transactionID and timestamp, both of which are assigned by the Fabric itself.
- Access control (.acl) : This file defines the access given to each Participant in the network. Participants such as Government officials on the various levels of the municipality have both, editing and viewing rights, and to prevent tampering of information, land-owners have only viewing rights.
- Query file (.qry) : Queries are written in bespoke Query language.

These files are zipped together to form a Business Network Archive (.bna), and a .card definition that gets deployed on the running Fabric network. Consequently, connection profiles and user credentials are used to install and access the .bna file to a distributed ledger.

Fig. 6 explains how Assets and Participants defined for the network together are used to define transactions, and how permission for every participant coupled with querying provides an accurate definition of the business network.

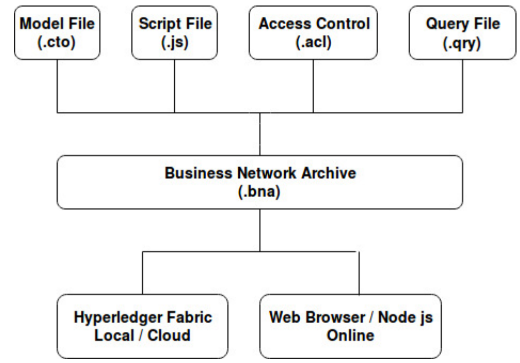

Fig. 6: Architecture of Hyperledger Composer

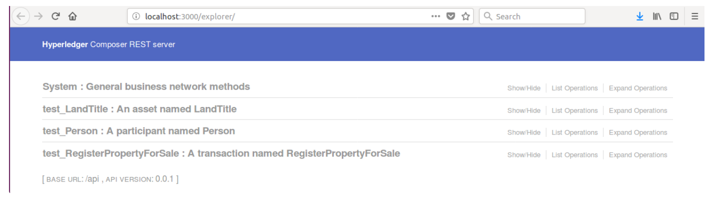

Fig. 7: Back-end using REST

The back-end runs on Hyperledger Composer which is linked to the front-end Angular system through the REST server using REST-API. It ensures superior control for the network administrator and seamlessly connects the aesthetics and the security of the system. A picture of the back-end system is shown in Fig. 7. Changes can be made through POST, GET and DELETE requests from the back-end.

Fig. 8 shows the front-end of our system which is linked the composer back-end system through REST-API. When a link or a button is clicked on the Angular front-end, REST-API links it with the corresponding POST, GET and DELETE requests on the Hyperledger Composer and performs identical alterations on the back-end. This creates a fluid system that runs uninterruptedly and provides a smooth user experience.

In Fig. 9 , Document_hash under Asset titled LandTitle refers to the documents of that property, which is uploaded on the IPFS (Interplanetary File System) network. Furthermore, only Assets, i.e., land properties that are listed true for sale can be sold through the Transactions section of the interface; this

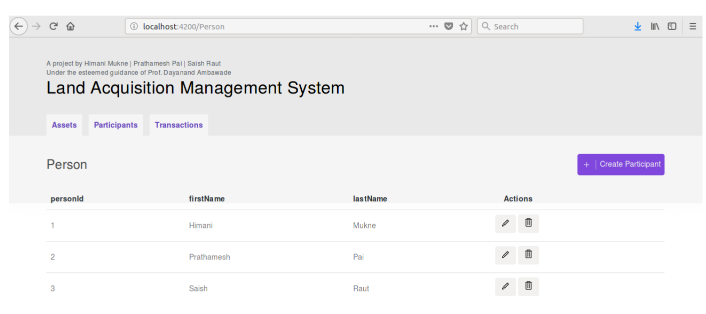

Fig. 8: Participant section on the front-end

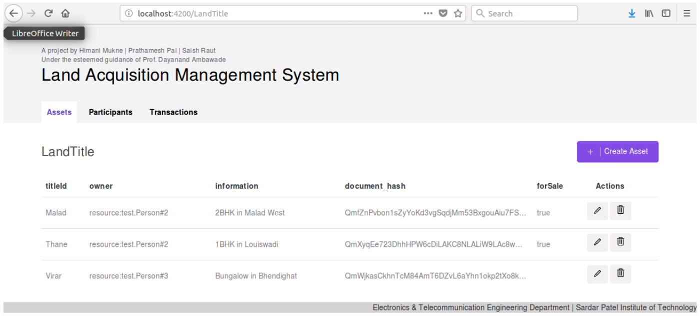

Fig. 9: Asset section on the front-end

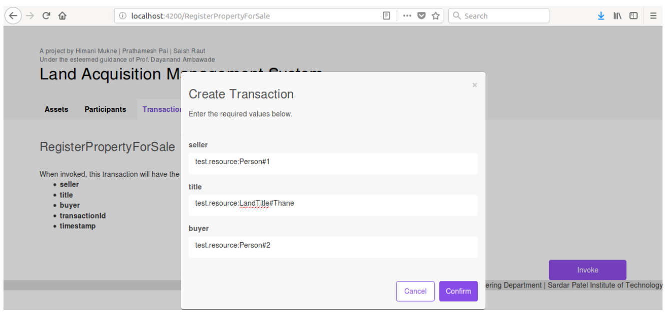

Fig. 10: Transaction section on the front-end showing transactionID and timestamp cannot be provided from the admin's end

selection can be done by the network administrator through the Boolean logic true/false.

For transactions to be legitimate, they need to have a qualifying timestamp and transactionID as well. Hyperledger Fabric ensures the authenticity of the created Transaction by safeguarding that the network administrator does not get to edit those two fields. Fig. 10 shows that transactionID and timestamp information is not provided by the user. The user only has to fill-in information about the buyer, the seller and the title of the land. The values of timestamp and transactionID fields are attached by Hyperledger Fabric only and can be viewed by anyone for transparency. Fig. 11 shows how the two fields got a qualifying value from the Blockchain for the same transaction performed in Fig. 10, where the prompt for those two fields was disabled from the admin's end (both front-end and back-end)

For a clean, decluttered interface, timestamp and transactionID are displayed on the back-end of our application.


```
[
  {
    "$class": "test.RegisterPropertyForSale",
    "seller": "resource:test.Person#1",
    "title": "resource:test.LandTitle#Thane",
    "buyer": "resource:test.Person#2",
    "transactionId": "31cce38b6302beb79a261e305252be830ae6d9edbbce16946698fabf7735d148",
    "timestamp": "2019-02-17T15:24:11.079Z"
  }
]
```


Fig. 11: transactionID, timestamp are qualified by the Blockchain only

```
himani@himani-HP-Notebook:~$ ipfs add Himani.pdf
added QmXyqEe723DhhHPW6cDiLAKC8NLALiW9LAc8wmdPPqJAUy Himani.pdf
himani@himani-HP-Notebook:~$ ipfs get QmXyqEe723DhhHPW6cDiLAKC8NLALiW9LAc8wmdPPqJAUy
Saving file(s) to QmXyqEe723DhhHPW6cDiLAKC8NLALiW9LAc8wmdPPqJAUy
 413.21 KB / 413.21 KB [========================================] 100.00% 0s
```

Fig. 12: The terminal screen shows uploading, downloading of documents from the IPFS network

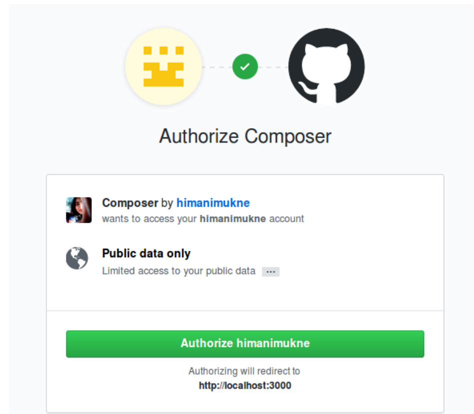

Fig. 13: OAuth application called "Composer" asking for permission to access the user's Github account credentials

Uploading and fetching files is done through Interplanetary File System. Fig. 12 is a picture of the terminal interface, which shows an example of how an administrator can add files pertaining to land related papers pertinent for comprehensive land-record maintenance on IPFS. A hash is generated for the uploaded document, which is then added to the Blockchain network, under the Asset section, where information about land (which is the Asset in this case) is added. The next command shows how an IPFS hash added on the Blockchain network can be used to fetch the document mapped against that hash on the IPFS network. The document is stored in the peer's computer memory with the same name as that of the hash.

Integration with Passport authentication enabled for Github login in this case adds an additional layer of security. Users can access the front-end and back-end of the Blockchain only after logging in through their Github accounts. The motivation behind including this step is to precisely track which users access the system information. Fig. 13 shows how the Passport asks users for authorization. Fig. 14 depicts the generation of access token after successful authorization through Passport. Fig. 15 represents that if the user bypasses authorization through Passport, any edits that he wishes to make to the system will not be reflected, instead, the system will through a 401 Authorization error.

VI. Enhancements for Efficiency

The execution efficiency of the system depends on key parameters such as the amount of records that can be altered in a given period of time, safekeeping of the record in the database making it available to only the users that are meant to have access to it, and determining what actions are ethically

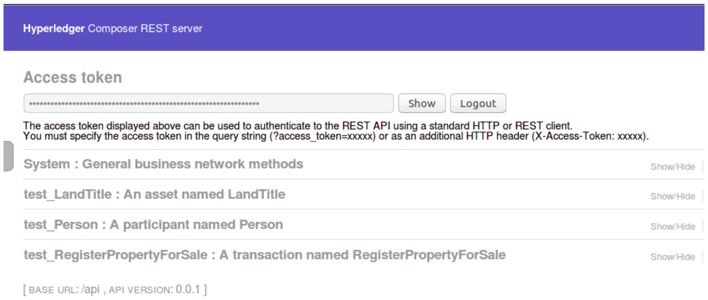

Fig. 14: Access token that is generated after authorization

Fig. 15: 401 Authorization error

permitted according to the law. There is always an empirical trade-off between the following three factors [20]:

- Performance: Amount of data being shared, number of peers i.e., the stakeholders such as land-owners and Government officials and their location, latency/throughput and batching characteristics affect the performance of the Blockchain. Division of area based on the record management traffic and not necessarily the geographical area of the municipality will hugely contribute towards improving the performance of the network. If more throughput is needed, more Peers should be added, so more entities can contribute their computational power to the network. For faster response time of the platform, efforts were made to store the minimum possible data on the actual Blockchain, which is achieved by using IPFS.
- Security: Security is one of the key values on which the system resides. The records that have been maintained should be accessed only by the stakeholders. This is done by identifying an individual through login systems and Passport integrations supported by Node. Alterations in the document can be made only by the concerned Government Authorities with the consent of the owners of the particular land. No other entity, including the network administrator has any right to delete a transaction entry once admitted in the Blockchain. While IPFS in itself is a safe, decentralized platform for storing files related to land records, anyone who gets his hands on the hash will get access to the file mapped by the hash. To protect against this, an additional encryption is provided by Asymmetric Encryption to encrypt the file before uploading it on the IPFS network.
- Resilience: In case of an attack on the system or servers, the databases will be secure and no damage will be done to the existing records. Malicious activity by a fraudulent user can be detected in the block-code and using Passports, the user can be identified and tracked. In a scenario where all the Committing Peers present in the network undergo a power failure and are unable to commit blocks of transactions to the Blockchain, the database will continue to maintain a record of all the transactions sent by the Client Application SDK, and these transactions will get grouped into blocks and committed to the Blockchain as soon as normal conditions are restored. For a robust system, Kafka algorithm (multiple Orderers) of ordering transactions into blocks is preferred over Solo (single Orderer), so that even if one Orderer fails, the system continues to run. The Orderer's job of deciding the number of transactions to be grouped as one single block is extremely crucial. If the block size is too small, multiple blocks need to be sent to the Endorsing and Committing Peers. If the block size is too large, even if a single transaction in the block is invalid, the whole block is discarded.

Hyperledger Caliper, a performance benchmarking tool for Hyperledger Fabric can further be used to manage the performance of the network. Currently, performance is indicated by [21] :

- Rate of success
- Throughput
- Latency of transaction
- Measure of peer computational resource consumption

VII. Results and Discussion

A brief comparison of this paper with existing technologies is shown in Table III.

VIII. Conclusion

This paper puts forth a state-of-the-art solution to curb and overcome the problems faced by the current Land Record Management System in India. The infusion of Blockchain into the system makes it tamper-proof, with little to no scope for fraudulence. The system brings together all the documents needed for establishing land ownership under a single decentralized peer-to-peer platform, gives access to the all the stakeholders involved in the up-keep of land records, and creates a robust platform for Land Record Management by distributing it over a Blockchain, making the record transparent, authenticated and secure. These documents can be used as concrete proofs in any land-based legal proceedings or disputes. Record maintenance is transparent and immutable due to the Chaincode and hence makes it forge-proof against inside as well as outside attackers or malicious users.

However, for any successful implementation of technology, seamless adoption by the involved parties is necessary. Hence, the biggest challenge for this solution would be to move existing land record management systems onto the one proposed in

Related Work	Proposed solution
Digital India Land Record Modernisation Programme (DIL-RMP) and Land Records Mission Mode Project (MMP) use a digitized but centralized approach to store and access land records. Documents are scattered across different offices and maintained offline [4], [5], [6]	This paper presents a decentralized network with an immutable history of transactions for a forge-proof system which can also maintain a record of the all the documents online
The model presented by Tatiana et al. employs Blockchain in Government auditing. However, there is dependence on inspectors for their assessment [8]	The proposed solution of this paper legitimizes land record transactions without any human intervention, through Chaincode logic
Nour et al. present eGov-DAO, a permissionless Blockchain wherein anonymous identities can view the database [9]	Hyperledger Fabric is a permissioned Blockchain that enables administrator to give access privileges to known, verified entities only
An experiment by Heng et al. in Chancheng District, seat of Foshan City, China provides a general idea for application of Blockchain in e-governmenance, however it does not give their actual implemention [10]	This paper's proposed solution uses Hyperledger Fabric Blockchain coupled with IPFS and Passport to implement e-governance model to create a system of trusted validators

TABLE III: Comparison of proposed solution with current systems

the paper, train the stakeholders to use the system, and ensure no offline settlements happen off the record.

IX. Future Work

Given the versatility of the Hyperledger Fabric technology, it finds its application in problem cases which require permissioned Blockchain - a network where known parties transact with each other but transparency of transactions and decentralization is demanded. The inclusion of the proposed solution as a method of maintaining land acquisition records will hugely help in securing such trades.

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References

[1] PRSIndia. Land Records and Titles in India [online] https://www.prsindia.org/policy/discussion-papers/land-records-and-titles-india [Accessed 30 Mar. 2019].

[2] Bashir, I. (2018). *Mastering Blockchain.* 1st ed. Birmingham, UK.: PACKT Publishing, pp.10,12,16-23,27-32,35-38,44,359,362-373.

[3] Courses.edx.org. Blockchain for Business-Introduction to Hyperledger Technologies [online] https://courses.edx.org/courses/course-v1:LinuxFoundationX+LFS171x+3T2017/course/ [Accessed 30 Mar. 2019].

[4] Vikaspedia.in. Digital India Land Record modernisation programme Vikaspedia. [online] http://vikaspedia.in/social-welfare/rural-poverty-alleviation-1/schemes-department-of-land-resources/computerisation-of-land-records [Accessed 30 Mar. 2019].

[5] Dilrmp.in. Digital India LR Modernisation Program [Online] http://dilrmp.gov.in/ [Accessed 29 Mar. 2019].

[6] Meity.gov.in. Land Records — Ministry of Electronics and Information Technology, Government of India [online] https://meity.gov.in/content/land-records [Accessed 30 Mar. 2019].

[7] S. Mohanty et al., "IGoSA A novel framework for analysis of and facilitating government schemes," *2015 IEEE 2nd International Conference on Recent Trends in Information Systems (ReTIS), Kolkata, 2015* pp. 290-295.

[8] T. Antipova, "Using Blockchain technology for government auditing," *2018 13th Iberian Conference on Information Systems and Technologies (CISTI), Caceres, 2018* pp. 1-6.

[9] N. Diallo et al., "eGov-DAO: a Better Government using Blockchain based Decentralized Autonomous Organization," *2018 International Conference on eDemocracy & eGovernment (ICEDEG), Ambato, 2018* pp. 166-171.

[10] H. Hou, "The Application of Blockchain Technology in E-Government in China," *2017 26th International Conference on Computer Communication and Networks (ICCCN), Vancouver, BC, 2017* pp. 1-4.

[11] S. Wang et al., "An Overview of Smart Contract: Architecture, Applications, and Future Trends," *2018 IEEE Intelligent Vehicles Symposium (IV), Changshu, 2018* pp. 108-113.

[12] T. Sato et al., "Smart-Contract Based System Operations for Permissioned Blockchain," *2018 9th IFIP International Conference on New Technologies, Mobility and Security (NTMS), Paris, 2018* pp. 1-6.

[13] S. Pongnumkul et al., "Performance Analysis of Private Blockchain Platforms in Varying Workloads," *2017 26th International Conference on Computer Communication and Networks (ICCCN), Vancouver, BC, 2017* pp. 1-6.

[14] Arxiv.org. Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains [online] https://arxiv.org/pdf/1801.10228 [Accessed 30 Mar. 2019].

[15] Decentralize.Today. Understanding Hyperledger in a bit more detail. [online] https://decentralize.today/understanding-hyperledger-in-a-bit-more-detail-3d40a37c74f2 [Accessed 30 Mar. 2019].

[16] IBM Developer. Blockchain basics: Hyperledger Fabric. [online] https://developer.ibm.com/articles/cl-Blockchain-hyperledger-fabric-hyperledger-composer-compared/ [Accessed 30 Mar. 2019].

[17] Protocol Labs. IPFS is the Distributed Web [online] https://ipfs.io/ [Accessed 30 Mar. 2019].

[18] Passport.js. Documentation. [online] http://www.passportjs.org/docs/downloads/html/ [Accessed 30 Mar. 2019].

[19] Hyperledger.org. Blockchain basics: Hyperledger Composer Overview. [online] https://www.hyperledger.org/wp-content/uploads/2017/05/Hyperledger-Composer-Overview.pdf [Accessed 30 Mar. 2019].

[20] Qassim Nasir et al., "Performance Analysis of Hyperledger Fabric Platforms" *Security and Communication Networks* Volume 2018, Article ID 3976093 14 pp

[21] Hyperledger Caliper. Hyperledger Caliper [online] https://hyperledger.github.io/caliper/ [Accessed 30 Mar. 2019].