

A Comprehensive Survey on Blockchain-Based Land Registry Systems: Dual-Signature Approaches for Secure and Transparent Property Management

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Abstract - Blockchain technology has emerged as a powerful paradigm for secure, transparent, and decentralized record management. In the context of land administration, where property records are prone to forgery, corruption, and inefficiencies, blockchain offers a promising alternative to conventional centralized systems. This paper presents a comprehensive survey of blockchain-based land registry systems with an emphasis on dual-signature authentication models, which require both the property owner and government authority to jointly approve transactions. The study explores key global implementations, including pilots in Georgia, Sweden, and Dubai, while analyzing technological trends such as Proof-of-Authority (PoA) consensus, smart contracts, and off-chain data management. Further, it identifies major challenges — legal, institutional, and technical — and discusses future directions involving Artificial Intelligence (AI), Geographic Information Systems (GIS), and decentralized storage for tamper-proof and citizen-centric land management. The insights derived from this survey aim to guide researchers, policymakers, and developers toward building next-generation blockchain-driven property governance systems.

Key Words: Blockchain, Land Registry, Dual-Signature Authentication, Proof-of-Authority, Smart Contracts, Property Management.

1. INTRODUCTION

Land and property ownership records form the foundation of national economies, influencing individual wealth, taxation, and infrastructure development. In many developing countries, including India, existing land registry systems are plagued by corruption, forgery, and administrative delays. A lack of interoperability between revenue, registration, and survey departments leads to conflicting ownership claims, while centralized record-

keeping systems remain vulnerable to manipulation and data loss.

According to a report by NITI Aayog, land disputes account for more than 60% of all civil cases in India. These issues stem from opaque procedures, manual verification processes, and the absence of immutable audit trails. The traditional “record of rights” framework, such as Maharashtra’s 7/12 extracts, relies heavily on physical documentation and manual mutation entries, making it susceptible to tampering.

Blockchain technology, with its core attributes of immutability, transparency, and decentralized trust, presents a transformative opportunity. By replacing centralized databases with distributed ledgers and introducing cryptographic validation, blockchain can ensure that once a property record is added, it cannot be altered or deleted without mutual consent. Furthermore, the introduction of a dual-signature mechanism, where both the landowner and authorized official must digitally approve each transaction, significantly enhances accountability.

This survey provides a structured examination of blockchain-based land registries, analyzing technical architectures, case studies, and research progress. The paper also emphasizes the practical relevance of Proof-of-Authority (PoA) consensus for government-led systems and highlights gaps that must be addressed to achieve real-world adoption.

2. BACKGROUND ON BLOCKCHAIN AND PROOF-OF-AUTHORITY CONSENSUS

2.1 Blockchain Fundamentals

A blockchain is a distributed ledger where transactions are recorded chronologically in blocks linked through cryptographic hashes. Each node maintains a copy of the ledger, ensuring redundancy and fault tolerance. Consensus algorithms guarantee that all

participants agree on the current state of the ledger, even in the presence of faulty or malicious nodes.

Smart contracts — self-executing programs deployed on the blockchain — allow predefined rules for ownership transfer, taxation, or dispute resolution to be automatically enforced. For land administration, smart contracts can encode property ownership and trigger transactions when both parties provide valid signatures.

2.2 Proof-of-Authority (PoA) Consensus

Among the various consensus mechanisms, PoA offers a balance between performance and accountability. Unlike Proof-of-Work (PoW), which requires computational effort, PoA relies on validator nodes operated by known, trusted entities, such as government departments or certified notaries. Each validator signs blocks using cryptographic keys, ensuring accountability and traceability.

PoA is particularly suitable for permissioned blockchain networks where participants are pre-approved. This model is ideal for land registries because it maintains efficiency (high throughput and low latency) while enabling auditable decision-making.

2.3 Dual-Signature Mechanism

The dual-signature approach enforces joint authorization between a property owner and a government officer. Using Elliptic Curve Digital Signature Algorithm (ECDSA) or EIP-712 typed signatures, the blockchain validates that both digital signatures match registered identities before a property mutation occurs. This ensures non-repudiation, prevents unilateral ownership transfer, and builds citizen confidence.

3. LITERATURE REVIEW OF GLOBAL BLOCKCHAIN PILOTS

Blockchain-based land registries have been explored through multiple government-backed pilots and academic prototypes worldwide. This section highlights some of the most influential implementations and research findings.

3.1 Republic of Georgia

The Republic of Georgia, in collaboration with Bitfury and the National Agency of Public Registry (NAPR), launched one of the first blockchain-based land titling systems in 2016–2017 [1]. The system anchored title deed hashes to the Bitcoin blockchain, ensuring immutable timestamps for property transactions. The pilot proved blockchain's ability to deter tampering and

increase public trust, although it required further legal integration for full deployment.

3.2 Sweden (Lantmäteriet)

Sweden's Lantmäteriet, together with ChromaWay and Telia, conducted an extensive blockchain experiment from 2016–2018 to digitize property transactions [2]. Using a private Ethereum-based platform, the project demonstrated a 90% reduction in processing time for sale agreements. However, legal acceptance of digital signatures and integration with national ID systems remained obstacles.

3.3 Dubai and Smart Dubai Initiative

The Dubai Land Department (DLD), under the Smart Dubai initiative, implemented blockchain to streamline property registration, mortgage validation, and rental agreements [3]. Dubai's leadership positioned blockchain as part of a nationwide digital transformation, connecting the DLD system with other government entities for tax, identity, and verification purposes.

3.4 Other Notable Pilots

Projects in Rwanda, Ghana, and the Philippines have explored blockchain for securing informal land tenure [8]. India has also initiated pilot studies in Andhra Pradesh and Telangana to record land titles on blockchain, integrated with the Bhulekh and DILRMP databases [9].

Table -1: Comparative Global Blockchain Land Registry Pilots

Country	Technology Used	Outcome Findings	Key Challenges
Georgia	Permissioned Blockchain (Bitfury)	Immutable proof of transactions	Legal integration
Sweden	Private Ethereum (ChromaWay)	Faster transaction processing	Digital signature validation
Dubai	Smart Dubai Framework	Multi-agency integration	Centralized control
India	PoA Network Prototype	Early-stage implementation	Interdepartmental adoption

4. ARCHITECTURAL FRAMEWORK OF DUAL-SIGNATURE BLOCKCHAIN REGISTRY

4.1 System Overview

The architecture of a blockchain-based land registry integrates four layers: the user interface, backend middleware, blockchain network, and off-chain data storage. Each plays a crucial role in ensuring data integrity and transaction traceability.

4.2 Transaction Workflow

The process begins when a property owner submits a request for ownership transfer. The government validator reviews and signs the request, after which the owner digitally signs confirmation using a wallet such as MetaMask. The system's smart contract verifies both ECDSA signatures, hashes document files, and writes the final record on the blockchain ledger.

Off-chain databases such as MongoDB or IPFS store large property documents, while only their cryptographic hashes are recorded on-chain to maintain efficiency and privacy.



Fig -1: System Architecture of Dual-Signature PoA-Based Land Registry (Blockchain-Based Property Ownership Process)

5. COMPARATIVE ANALYSIS OF CONSENSUS MECHANISMS

Different consensus mechanisms exhibit varying trade-offs between security, scalability, and energy efficiency. Table -2 summarizes the comparison.

Table -2: Comparison of Consensus Mechanisms for Land Registries

Mechanism	Advantages	Limitations	Suitability
PoW	Highly secure, proven model	High energy consumption	Public blockchains
PoS	Energy-efficient, faster validation	Validator monopoly risk	Financial systems
PoA	Low latency, controlled access	Requires trusted validators	Government registries
PBFT	Fault-tolerant, fast consensus	Limited scalability	Consortium chains

PoA emerges as the most suitable choice for government-controlled property registries, balancing efficiency with verifiable accountability.

6. CHALLENGES AND RESEARCH GAPS

Despite technological maturity, the real-world deployment of blockchain land registries faces several challenges:

6.1 Legal Recognition

Blockchain records currently lack legal standing in most jurisdictions. Legislative amendments are required to make digital blockchain entries admissible in courts as proof of ownership.

6.2 Data Privacy and Security

Land data often includes personal identifiers. Maintaining transparency while safeguarding privacy requires advanced cryptographic approaches such as zero-knowledge proofs and selective disclosure mechanisms.

6.3 Interoperability

Integrating blockchain registries with legacy systems such as Bhulekh and the DILRMP framework in India remains a major obstacle. APIs and middleware solutions can bridge these systems, but uniform standards are yet to be established.

6.4 Scalability

As blockchain adoption grows, transaction throughput and storage requirements increase significantly.

Techniques like sharding, layer-2 scaling, and hybrid chains must be explored to sustain national-level operations.

6.5 User Adoption

Citizen participation is critical to success. Simplified interfaces, multilingual support, and public awareness initiatives can encourage engagement and build trust in blockchain platforms.

7. FUTURE DIRECTIONS

7.1 Integration with AI and GIS

Artificial Intelligence (AI) can analyze transaction trends to detect fraudulent activities. Geographic Information Systems (GIS) integration allows spatial mapping of properties, reducing boundary disputes and enhancing cadastral accuracy.

7.2 Decentralized Storage and Identity

Decentralized storage platforms like IPFS and Filecoin ensure document permanence and authenticity. Similarly, Decentralized Identifiers (DIDs) can validate user identities without exposing sensitive data to centralized authorities.

7.3 Multi-Stakeholder Governance

Future systems may operate as multi-node consortiums where government bodies, banks, and insurance firms act as validators. This distributed governance can enhance resilience and eliminate single points of failure.

7.4 Cross-Border Applications

Blockchain's interoperability can facilitate cross-border property management and international mortgage verification, benefiting citizens with multi-country holdings.

8. CONCLUSION

Blockchain has the potential to revolutionize land administration by ensuring transparency, efficiency, and accountability. Dual-signature Proof-of-Authority systems represent a practical evolution of blockchain's capabilities, blending decentralization with necessary government oversight. Through the analysis of existing global pilots, this paper underscores the importance of technical design, policy alignment, and public participation in achieving a secure and scalable blockchain-based land registry ecosystem.

Future work should focus on developing hybrid frameworks integrating blockchain, AI, and GIS technologies to achieve a seamless, verifiable, and citizen-centric land governance system.

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