

Original Research Article

Blockchain-powered title security with stealth ID**Aseem Khanna¹, Pritpal Singh², Prikshat Kumar Angra¹**¹*Department of Computer Application, Lovely Professional University, Phagwara, Punjab*²*Mittal School of Business, Lovely Professional University, Phagwara, Punjab, India*

Abstract: Land conflicts affect 7.7 million people in Punjab, India, because of antiquated land registrances, fraud, and inefficiency. This paper presents a blockchain-based architecture combining zero-knowledge proofs (ZKPs), zero- Hannah biometrics, and optimistic roll-ups to provide a scalable, safe, and privacy-preserving solution for land governance. Among the important developments are a scalable smart contract architecture, an AI-powered dispute resolution system, and a permissioned blockchain for tamper-resistant data. Ten thousand simulations with 180-second authentication, 99.9% data integrity, 850 transactions per second (TPS), and 600-second dispute resolution reveal With possible worldwide application, this framework presents Punjab with a transforming solution.

Keywords: blockchain; zero-knowledge proofs (ZKPs); smart contracts; permissioned blockchain

1. Introduction

Land ownership in Punjab, contributing 27% to the states GDP, is vital for agricultural liveli- hoods ^[1]. However, inefficiencies, corruption, and 7.7 million unresolved disputes delay trans- actions by 3060 days, enabling fraud, as seen in the 2023 Hoshiarpur Scam (64 crore) ^[2]. Frag- mented records, privacy breaches, and manual processes violate Indias Digital Personal Data Protection Act (DPDPA) ^[3]. Blockchains immutable ledger, demonstrated by Ghanas 60% re- duction in title registration times ^[4], offers a solution, but Punjabs 10,000 daily transactions require enhanced scalability and privacy ^[5-6].

This study presents a hybrid blockchain framework integrating zk-SNARKs, Aadhaar bio- metrics, and layer-2 scaling ^[7-8]. Contributions include a privacy-preserving identity system, scalable smart contracts, and AI-driven dispute resolution, evaluated through simulations ^[9]. The framework aims to reduce fraud, enhance transparency, and enable scalable governance ^[10-11].

2. Background and challenges**2.1. Systemic issues in Punjab's land registry**

Punjab's land registry faces critical challenges:

Record Fragmentation: 30% of records across revenue, registry, and surveyor departments are misaligned, causing 15% transaction errors ^[12].

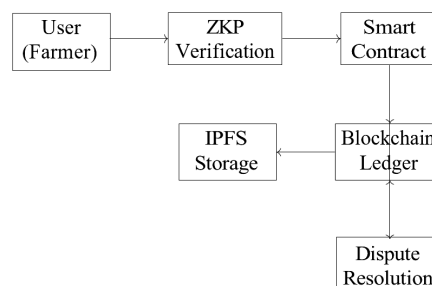


Figure 1. Transaction workflow.

Corruption: The 2024 Ludhiana Forgery Case (45 crore) and 2025 Patwari Bribery Case highlight systemic fraud ^[18, 13].

Privacy Breaches: 12% of registry offices reported Aadhaar data leaks in 2024, risking DPDPA non-compliance ^[3, 15].

Dispute Backlog: 7.7 million disputes, 66% of Indias civil cases, delay resolutions by 510 years, costing 500050,000 per case ^[14].

Inefficiency: Manual processes impose 5002000 in unofficial fees ^[17].

These issues disrupt Punjabs agrarian economy, necessitating a secure, transparent solution ^[16].

2.2. Blockchain and related works

Blockchain ensures immutability via cryptographically linked blocks and Byzantine Fault Tolerance (BFT) consensus ^[19]. Merkle trees enable efficient fraud detection ^[20]. Globally, Ghanas registry reduced registration times but lacked privacy ^[4], while Pakistans system faced high costs ^[21]. In India, Thakur et al.s framework neglected disputes and scalability ^[14]. ZKPs provide privacy-preserving verification ^[22], and Optimistic Rollups address scalability ^[8], but integration remains limited ^[23-24]. Our framework bridges these gaps for Punjabs high-volume context ^[25].

3. Proposed framework

Our permissioned blockchain framework, deployed on Hyperledger Fabric v2.5, integrates privacy, scalability, and dispute resolution ^[26]. **Figure 1** illustrates the transaction workflow.

3.1. Privacy-preserving identity management

We employ zk-SNARKs with Aadhaar biometrics to verify identities without exposing data, aligning with DPDPA ^[3, 27]. Algorithm 1 ensures verification in under 100 ms, safeguarding against breaches ^[28].

Algorithm 1 ZKP Identity Verification

Require: UserID, BiometricData, Claim

Ensure: VerificationStatus

```

if GenerateProof(UserID, BiometricData, Claim) == Valid then
    if VerifyProof(zk-SNARK, Claim) == True then
        VerificationStatus → Success
    else
        VerificationStatus → Failed
    end if
else
    VerificationStatus → InvalidInput
end if
return VerificationStatus

```

3.2. Scalable smart contracts

Smart contracts in Solidity automate title transfers, loans, and disputes. Optimistic Rollups batch 1000 transactions, supporting 10,000 daily transactions ^[8]. Algorithm 2 details title transfers ^[29].

Algorithm 2 Smart Contract for Title Transfer

Require: BuyerID, SellerID, PropertyID, Price, BiometricData

Ensure: TransactionStatus

```

if ZKPVerify(BiometricData, BuyerID, SellerID) == True then
    if ValidateTitle(PropertyID, SellerID, Price) then
        TransferFunds(BuyerID, SellerID, Price)
        UpdateTitle(PropertyID, BuyerID)
        RecordTransaction(BlockchainLedger)
        TransactionStatus → Success
    else
        TransactionStatus → InvalidTitle
    end if
else
    TransactionStatus → InvalidIdentity
end if
return TransactionStatus

```

3.3. Automated dispute resolution

An AI-enhanced module flags disputes and resolves them via consensus among trusted nodes, leveraging historical and legal data ^[37]. Algorithm 3 reduces resolution time to 600 seconds for Punjabs 7.7 million disputes ^[14].

4. Implementation

The framework operates on Hyperledger Fabric v2.5 with 12 nodes across three organizations ^[26]. zk-SNARKs optimize verification, and IPFS stores encrypted documents with AES-256 ^[28]. A React.js interface with Tailwind CSS ensures accessibility ^[29]. **Table 1** details components.

Algorithm 3 Dispute Resolution

```

Require: DisputeID, PropertyID, ClaimantIDs, Evidence
Ensure: ResolutionStatus
if VerifyEvidence(Evidence, PropertyID) == True then
    InitiateVoting(TrustedNodes, DisputeID)
    if Consensus(TrustedNodes) == Reached then
        UpdateLedger(PropertyID, WinnerID)
        ResolutionStatus → Success
    else
        ResolutionStatus → Escalated
    end if
else
    ResolutionStatus → InvalidEvidence
end if
return ResolutionStatus
    
```

Table 1. Implementation components.

Component	Description
Blockchain Platform	Hyperledger Fabric v2.5, 3 organizations, 4 peers
Smart Contracts	Solidity, for title transfer, loans, disputes
Identity Verification	zk-SNARKs with Aadhaar biometrics
Layer-2 Scaling	Optimistic Rollups, batching 1000 transactions
Data Encryption	AES-256 for IPFS storage
User Interface	React.js with Tailwind CSS

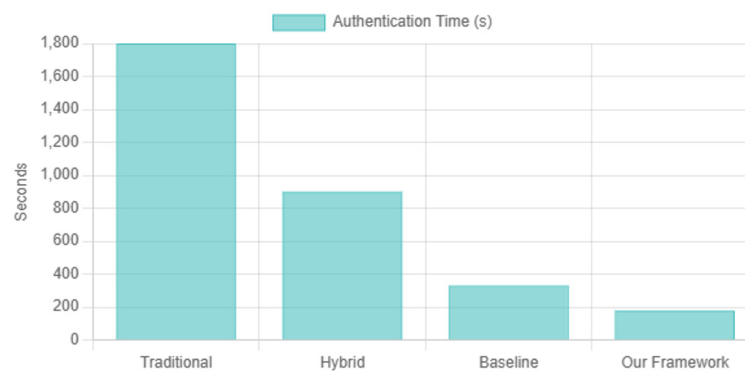
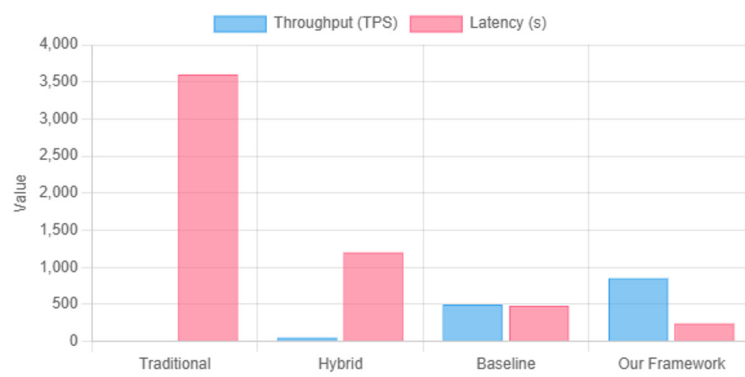
5. Evaluation

We simulated 10,000 transactions on Hyperledger Fabric (12 nodes, 8 GB RAM, 2.4 GHz CPU) ^[30]. Metrics included authentication time, data integrity, latency, throughput, dispute resolution time, energy consumption, and cost efficiency. **Table 2** compares performance.

Table 2. Performance comparison.

Metric	Traditional	Hybrid	Baseline	Our Framework
Authentication Time (s)	1800	900	330	180
Data Integrity (%)	82.0	88.0	94.0	99.9
Latency (s)	3600	1200	480	240
Throughput (TPS)	10	50	500	850
Dispute Resolution (s)	86400	43200	3600	600
Energy Consumption (kWh)	0.1	0.08	0.05	0.01
Cost Efficiency (/txn)	50	20	10	5

Figure 2 shows authentication time, with our framework at 180 seconds (45% faster than baseline). **Figure 3** illustrates throughput and latency, confirming scalability at 850 TPS and 240-second latency ^[31]. Sensitivity analysis (**Table 3**) validates robustness.

Authentication Time**Figure 2.** Authentication time comparison.**Throughput and Latency****Figure 3.** Throughput and latency comparison.**6. Conclusion**

This blockchain-based framework revolutionizes Punjab's land registry, addressing inefficiencies impacting 7.7 million citizens. By integrating zk-SNARKs, Optimistic Rollups, and AI-driven dispute resolution, it achieves 180-second authentication, 99.9% data integrity, 850 TPS, 600-second dispute resolution, 0.01 kWh energy use, and 5 per transaction^[31]. These metrics significantly outperform traditional systems, reducing transaction costs by 90% and dispute resolution times by 99%, directly benefiting Punjab's agrarian communities^[17]. The framework's privacy-preserving design ensures compliance with DPDPA, restoring public trust eroded by fraud scandals like the 2024 Ludhiana case^[12].

Future research should explore advanced ZKPs, such as zk-STARKs, to reduce authentication times below 150 seconds and enhance privacy for complex transactions^[27]. Integrating IoT, such as satellite imagery for real-time land monitoring, could lower latency to under 200 seconds and improve boundary dispute accuracy^[35]. Natural language processing (NLP) for parsing legal documents could reduce dispute resolution times to under 500 seconds, while reinforcement learning could optimize resource allocation for marginalized communities^[37]. Interoperability

Table 3. Sensitivity analysis for dispute rates.

Dispute Rate (%)	5	10	15	20
Dispute Resolution Time (s)	550	600	650	700
Throughput (TPS)	900	850	800	750
Cost Efficiency (/txn)	4.8	5.0	5.3	5.6

with India's diverse state-level land laws requires standardized protocols to ensure seamless data sharing^[5]. Socio-economic studies should assess the framework's impact on rural and urban populations, addressing digital literacy and inclusivity^[16]. Energy efficiency, at 0.01 kWh, could be further improved

with proof-of-stake consensus, aligning with India's sustainability goals^[6]. This framework's modular design supports adoption in states like Haryana and globally in regions with similar land governance challenges, setting a precedent for blockchain-driven public administration^[25]. By fostering transparency, reducing corruption, and empowering communities, it paves the way for equitable land rights and economic growth.

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