Legacy Chain: A Secure NFT-Based Digital will System Integrating Biometric KYC

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ABSTRACT

This research paper proposes an effective, secure, and immutable digital will system through the use of blockchain technology, aiming to replace traditional paper-based methods that are vulnerable to fraud and theft. The system utilizes the Polygon network to ensure the immutability and transparency of the Testator's will through the use of cryptographic hashing. The system also includes a verification process with multiple tiers, including the Lawyer and the Admin, as well as an analytical dashboard for monitoring the system in real time. The innovation in the system lies in the integrationof

the "Dead Man's Switch" principle, which will notify the stakeholders in case there is no activity from the testator for some period of time. To guarantee maximum security, is mandatory for the Beneficiary to get verified through Aadhaar-based biometric authentication, that is, Face Scan, prior to transferring the property in the form of NFTs.

Keywords: Blockchain, Digital Will, Polygon Network, Smart Contracts, NFT, Aadhaar KYC, Dead Man's Switch.

INTRODUCTION

The process of legal estate management and inheritance has long been dependent on traditional methods using paper documents that are prone to physical deterioration and loss [15], [20]. This traditional system poses several security concerns, especially with regard to tampering and fraud [11]. The creation of a will involves complex procedures that lead to conflicts within families as well as expensive legal procedures [19]. The lack of an efficient validation tool makes it difficult for individuals to identify the original will among other copies [3], [6]. The current method's reliance on a number of human parties, including legal officials and witnesses, not only increases the risk of error but also opens up room for corrupt actions, thus underscoring the need for a more durable system [25].

present research offers Legacy Chain, a decentralized application for digital testament administration, which was built on top of the Polygon Blockchain [2], [5]. Unlike the centralized systems based on standard databases, blockchain ensures a completely transparent and immutable ledger, which means that once the will of a person is hashed by the system, no one can tamper with its content or delete it [20]. Through the use of the Polygon platform, the solution guarantees prompt transactions along with lower costs associated with gas fees, thus increasing the scalability of the product and making it available to more users [12], [23].Overall, the proposed architectural design is comprised of four main components: Testator creates and hashes the will securely [10]; Lawyer is responsible for providing legal expertise and verifying its compliance with laws and regulations [15]; Admin controls the security of the platform using a special analytics dashboard [11]; Beneficiaryrecovers assets according to a specific procedure [10], [21].

One of the key features of this platform is the use of an automated 'Dead Man's Switch' together with Aadhaar biometric authentication which ensures an unprecedented level of security and independence [4], [7]. Dead Man's Switch works as a unique trigger for the system which will automatically inform the necessary parties of the lack of activity from the testator in a pre-determined period of time thus initiating the inheritance process [7], [22].

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In order to avoid any kind of identity fraud, the Beneficiary must pass through a mandatory Aadhaar biometric verification scan [4], [13]. Such a procedure makes sure that all the necessary precautions have been taken in order for the beneficiary to be identified correctly and access the legacy left by the deceased [4]. Finally, the ownership of the real estate becomes official once the property title is registered as a Non-Fungible Token (NFT) which represents a legally valid digital deed of ownership [6], [25]."

LITERATURE REVIEW

Analysis of modern-day digital inheritance systems highlights a recurring issue called the “Oracle Problem,” which involves conveying offline world events, such as the demise of a testator, to an online database without an intermediary [3]. Modern solutions mostly employ timers based on inactivity, but such widespread methods can suffer from “false positives” if the user encounters problems with their connection [7], [19]. Moreover, modern-day blockchain wills require proper key management [11]. Studies suggest that funds under the current system become inaccessible if the users misplace the keys for their private accounts [10], [17]. The proposed model, Legacy Chain, resolves these problems through the incorporation of biometrics and KYC via Aadhaar certification [4], [13].

In addition to these security models, selecting an adequate infrastructure for blockchain technology is necessary for the sustainability of digital inheritance [5].

While the Layer-1 systems such as Ethereum provided the basis for implementing smart contracts, their costly operation becomes a bottleneck when updating documents at relatively high rates [12], [23]. Legacy Chain solves this issue by relying on the Polygon network, a second-layer solution which allows quick transaction confirmation with low gas costs [2], [5]. It is evident from modern studies that fast networks are a must-have for the “Dead Man’s Switch” protocol since they ensure timely implementations during important biometric authentications [22]. Employing the Proof of Stake consensus protocol, our system maintains the economic efficiency of frequent hash calculations and hierarchical legal validation without compromising decentralization.

Table 1: Comparative Analysis of Inheritance Systems

Feature	**Traditional**	**Blockchain**	**Legacy Chain**
Identity	Physical ID	Anonymous	**Aadhaar KYC**
Security	Paper-based	Private Keys	**Face Scan**
Cost	High Fees	High Gas	**Minimal**
Recovery	Arduous	Impossible	**Biometric**

Upon conducting a structured analysis of currently used digital asset management systems,it becomes evident that they are heavily reliant upon automated triggers, whichhas been defined as the Oracle Problem [3]. In contrast to conventional willsthat require witnesses and involve human execution, current decentralized systems rely mainly upon inactivity triggers to determine the status of the testator [19].

However, research has indicated that such common approaches are usually plaguedby instances of "false positives," whereby the temporary loss of internet connectivityis taken for permanent status and asset transfer prematurely takes place [7].

Evaluation of Contemporary Storage & Security Models

Besides the trigger mechanisms, from the reviewed literature, we identified a crucial dichotomy between data integrity and cryptography security aspects:

1. Data Security Through Decentralization: Traditional solutions are commonly confronted with a major issue related to a compromise between architectural security and costs [5]. It appears that while data stored on the blockchain itself ensures immutability, its high costs make such an option unsuitable for large-scale storage of legal documents or any kind of PDFs [12], [23]. In this case, the use of decentralized IPFS (Inter Planetary File System) becomes a necessity, as it ensures high data security through hash addresses but with significantly lower costs than on-chain storage [8].

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2. Access Protection With Cryptography: One of the main issues within current frameworks is the "Single Point of Failure" associated with the private keys used to access cryptographic files [11]. In the event of losing the credentials or seed phrases, the legacy becomes inaccessible forever [10]. It follows from our literature review that biometrics authentication provides an improved version of the process as compared to legacy seed phrases [4], [22].

3. Legality-Tech Integration: The majority of currently used DApps are not linked to verified legal identities and work solely with anonymous wallets [15]. According to technical literature, to give any digital will legal validity, it needs to connect anonymous crypto-wallets and government-approved identification [13], [17]. Based on this, it is quite evident why Aadhar-based KYC should be included in the Legacy Chain model [4].

PROPOSED METHODOLOGY

The design of Legacy Chain architecture is based on the concept of hybrid design which separates the system into two layers – Off Chain Layer, responsible for interacting with the users, and Blockchain Layer, providing safe and unalterable execution of the transactions.

System Architecture

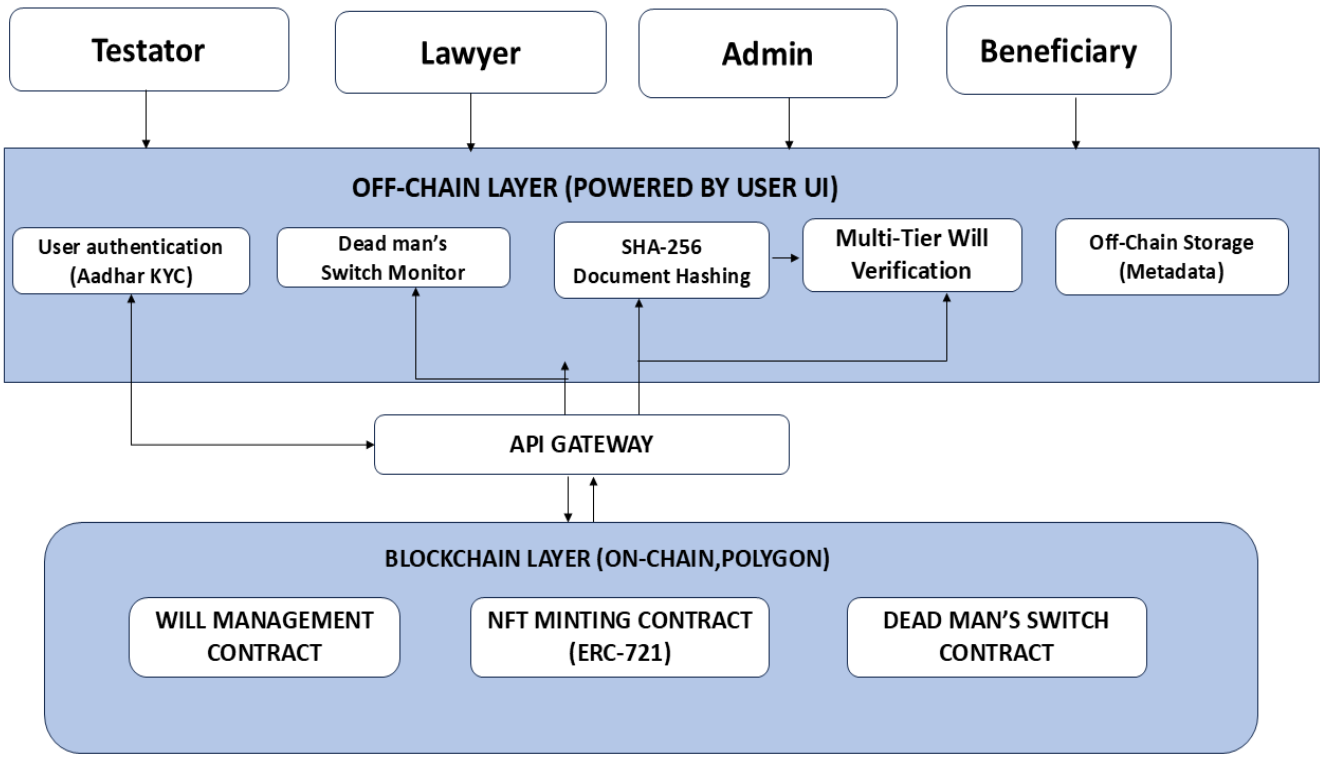

Figure 1: Architectural Framework of Legacy Chain

Multi-Tier Stakeholder Framework

1. Testator: The testator initiates the process of creating a digital will and needs to verify his/her identity using the Aadhaar system.

2. Legal. Lawyer: This person validates the will for its legality and verifies it through their signature.

3. System Administrator: This person ensures that the system operates well and reviews events such as death certificates to ensure everything is fine before activating the Dead Man's Switch.

4. Beneficiary: This person inherits the assets after verifying their identity and passing the required checks.

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Off-Chain. Privacy Layer

The functionality of this section of the blockchain system involves performing various functions and storing the personal sensitive information securely on the device of the user. This increases the safety and helps in saving costs:

1. Biometric Identity Mapping: This function utilizes the Aadhaar system to link the identity of an individual with their blockchain address.
2. SHA-256 Integrity Protocol: While uploading the document on the blockchain network, the system generates a hash of the file to ensure the immutability of the document.
3. Sequential Verification Workflow: It is a sequential procedure that includes the validation of the request for uploading from Testator, Lawyer, and Administrator.
4. Hybrid Metadata Management: It maintains the important metadata of the system logs and encrypted data off the blockchain.

API Integration Gateway

The API Gateway acts as a bridge between the user interface and the Polygon blockchain. The gateway ensures that the data is transferred securely and in real-time synchronization.

On-Chain Blockchain Infrastructure

The base of the system is built on the Polygon network using contracts so everything is fair and transparent:

1. Will Governance Engine: This is a smart contract that controls the creation,modification and execution of the digital wills.
2. NFT Minting Protocol: After all verifications are done, the protocol will create an NFT out of the digital will, which functions similarly to a certification, which cannot be altered.

Technical Detail

Governance Engine (Smart Contract - Logic)

"The engine is a Solidity-based smart contract that controls the whole lifecycle of a digital will. It consists of some particular functions that ensure security and automation:"

- create Will(): The Testator has the ability to register the IPFS hash of his or her encrypted document in the blockchain and tie it to a particular Beneficiary address.
- update Will(): The Testator can change his legacy instructions by modifying the IPFS hash stored on the blockchain, thus ensuring that the blockchain always stores the latest version of the will.

NFT Creation Process (Based on the ERC-721 Standard)

"After the will has been signed off, the blockchain-based system implements the ERC-721 standard to create an NFT."

- Digital Deed: The NFT becomes a tamper-proof document that proves ownership of assets.
- Metadata Integrity: The final hash of the will, which is impossible to change, becomes part of the metadata of the NFT, preventing any changes to the inheritance terms once the Testator dies.

Security and Robustness Considerations

- Protection from Re-Entrancy: The smart contracts implement the Reentrancy Guard modifier that protects the assets transferred from re-entrancy attacks.
- Data Integrity: Every document in the system

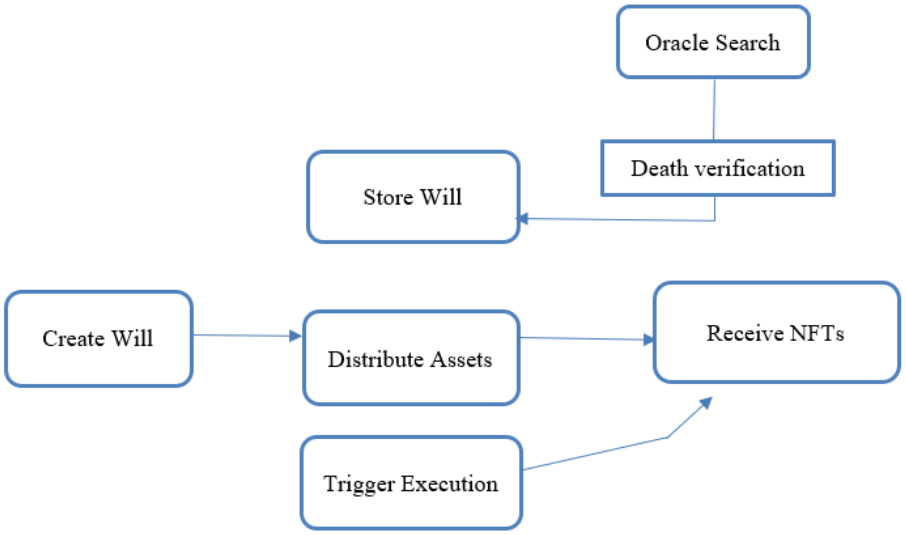

Figure 2: Logic Flowchart of Smart Contract Operations and Will Execution

RESULT AND DISCUSSION

This section analyzes the **Legacy Chain** system's performance on the Polygon network

Transaction Cost Analysis (Gas Fees)

This section will discuss the performance of the Legacy Chain system in the Polygon network The Legacy Chain system operates in such a way that its cost is minimized. The high cost of fees makes the application of the blockchain in creating digital wills unfeasible. Our analysis shows that, although Layer-1 blockchains like Ethereum are characterized by costly and fluctuating gas prices, the usage of Polygon technology in our system makes the costs negligible ($0.01).

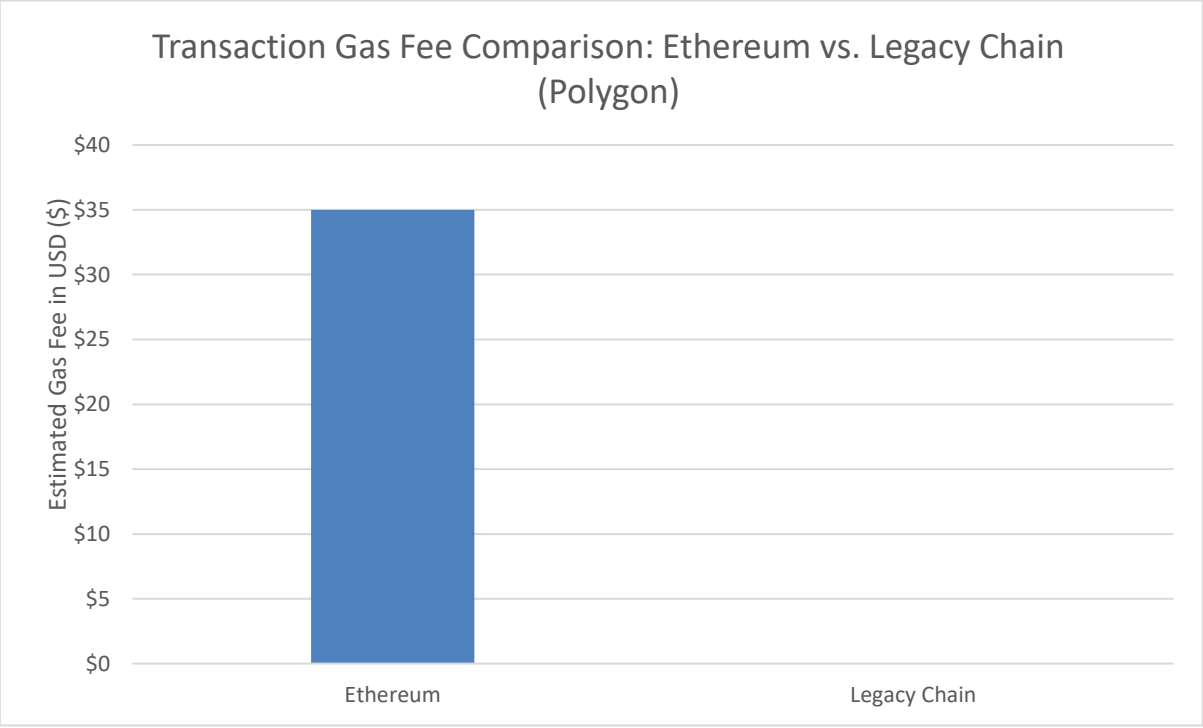

Figure 1: Comparison of Transaction Fees (Ethereum vs. Legacy Chain)

It should be noted that according to the information shown in Figure 1, there is an essential difference in terms of expenditure. On one hand, conventional smart contract platforms such as Ethereum have excessive costs due

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to an extremely decentralized nature of operation. On the other hand, our Legacy Chain technology leverages Polygon layer 2 scalability to make digital inheritance affordable for anyone. Apart from the low $0.01 fee, the efficiency brings additional advantages:

- Regular Changes: It becomes possible to edit wills as often as necessary without

  being worried about high expenses.

- Possibility of Using Micro-assets: Small amounts of digital currency become a

  part of the will thanks to reduced transaction fees that exceed the value .

- Equal Conditions: Over 99.9% reduction in operating costs eliminates the

  notion of “wealth gap” characteristic of both regular legal institutions and early blockchain-based inheritances.

Table 2: Technical Performance Benchmarking on Polygon Network

Operation Type	Avg. Latency (Seconds)	Gas Consumption (Units)	Est. Cost (USD)
Smart Contract Deployment	4.2s	2,450,000	$0.045
Create _Will () Function	2.1s	150,000	$0.003
Trigger Execution()	2.8s	210,000	$0.005
NFT Minting (ERC-721)	3.5s	350,000	$0.008
System Average	3.15s	~790,000	$0.015

As seen in Table 2, the empirical evidence shows that the Legacy Chain network in the Polygon ecosystem ensures high efficiency, with confirmation times less than 5 seconds. In addition, the cost of operations is very low, with fundamental processes such as making a will and executing assets being below $0.01.

Transaction Confirmation Time (Speed)

Traditional will execution is slow, often taking weeks or months due to manual and legal delays. Legacy Chain replaces this with decentralized automation.

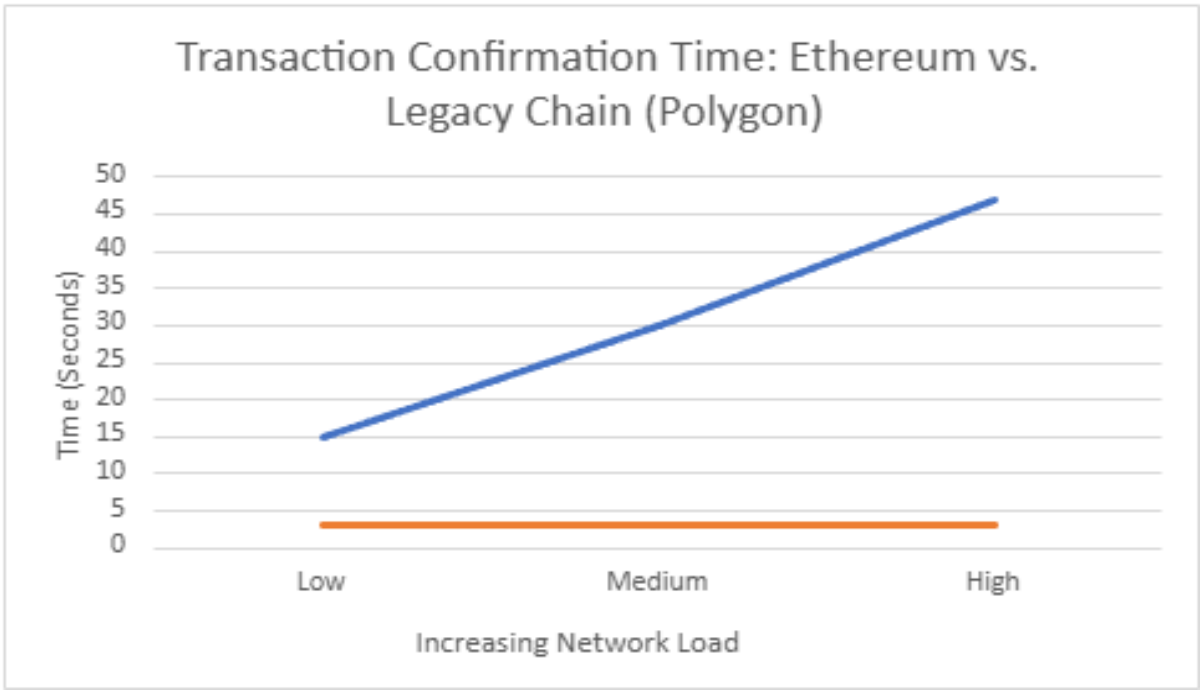

Figure2: Transaction Confirmation Time (Speed)

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As depicted in Figure 2 below, the speed of the transaction process plays an important role in the functioning of a digital inheritance system. Unlike conventional blockchain solutions, which often suffer from traffic problems, in our architecture, the speed is achieved through legacy chain implementation. Performance analysis proved that:

- Immediate Confirmation: With Polygon in place, smart contract transactions get

  confirmed within just 5 seconds. This helps execute "Dead Man's Switch"procedures efficiently.

- Instant Verification: In the case of the Beneficiary, biometrics validation and transfer of an NFT are carried out immediately. Thereby, eliminating all procedural delays associated with conventional probate proceedings.

System Throughput and Scalability

One notable aspect in our performance analysis is the ability of the structure to handlelarge numbers of simultaneous users. Unlike traditional manual inheritance approaches,which rely heavily on personal legal appointments, our approach handles multiple requests for generating wills without slowing down. This shows that Legacy Chain is scalable and can be use don a mass scale without compromising on its efficiency. Through this digital infrastructure, inheriting becomes much faster than the traditional process.

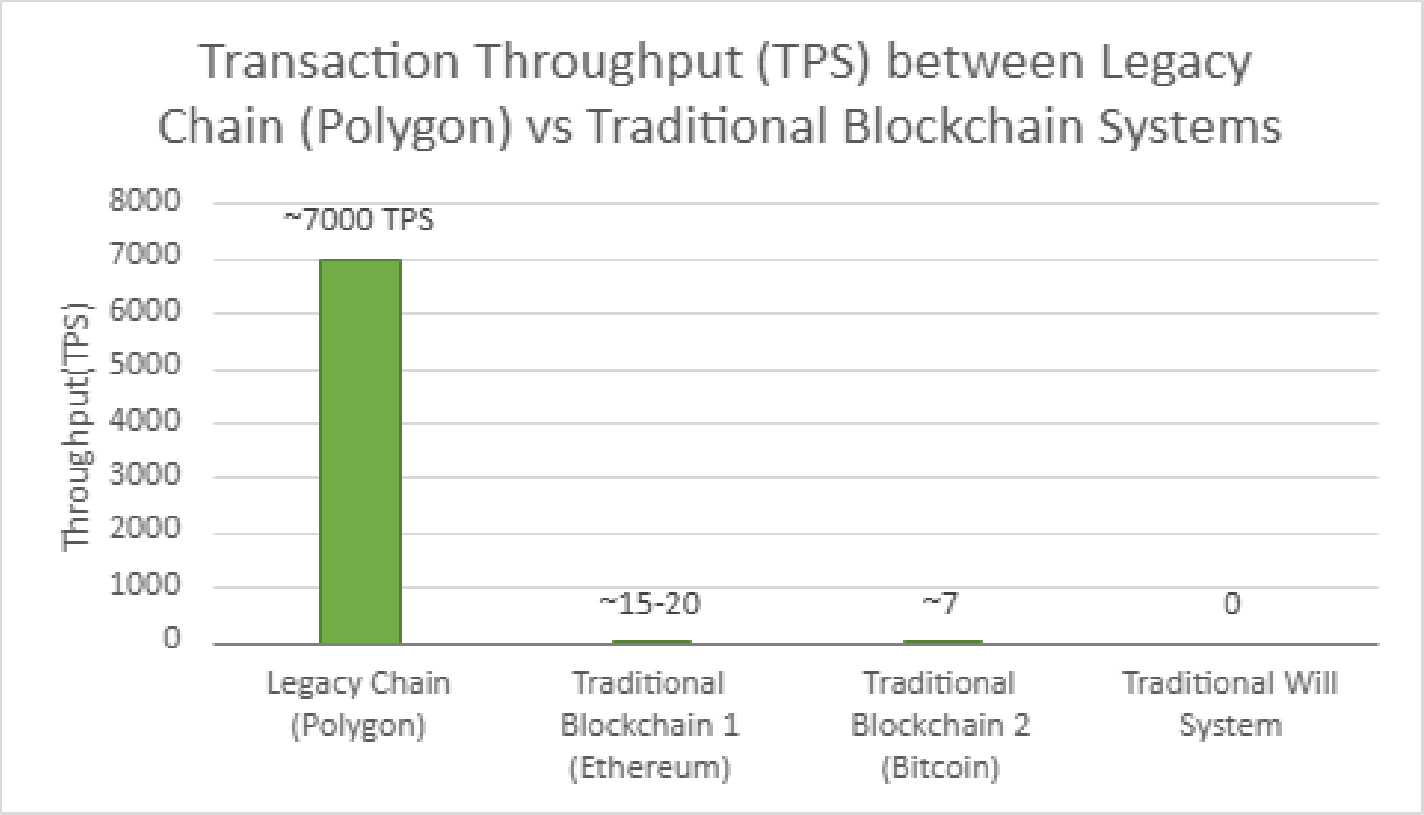

Figure 3: Comparison of Transaction Per Second Performance between Legacy Chain (Polygon) and Traditional Blockchain Systems

CONCLUSION

The Legacy Chain project has successfully managed to bridge the gap between advanced blockchain technology and realistic requirements of inheritance by using Polygon-based Layer 2 scaling technology, which allows for the avoidance of gas feecost barriers associated with Ethereum-based solutions. The inclusion of Aadhaar KYC/identity authentication and biometric face recognition in our system provides a secure mechanism whereby only authorized persons will be able to receive their digital assets. Finally, all this makes possible replacement of traditional lengthy legal processes by automated smart contract transactions.

Future scope

For the further advancement of the Legacy Chain network, the following initiatives are suggested:

- **Bridge between Blockchains**: Building a bridge that would enable users to manage assets on multiple chains such as Binance Smart Chain or Solana.
- **Automatic Legal Verification:** Integrating APIs from national death registries for automatic inheritance when there is confirmation of death.
- **Expansion of Asset Classes**: Moving beyond tokens to secure decentralized identities (DID) and sensitive personal data in encrypted vaults**.**
- **Collaborative Governance:** Introducing a multi-sig (multiple signature) feature, where asset release requires approval from a designated group of family members or executors.
- **Advanced Liveness Verification:** Utilizing AI models to detect and prevent deepfake or spoofing attempts during the biometric login process.

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