A Blockchain and InterPlanetary File System (IPFS) Based Smart Contract Framework for Preventing Certificate Fraud in Academia

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***Abstract*—This initiative aims to revolutionize academic credential verification by creating a decentralized school diploma issuance platform. With blockchain technology, students can securely maintain their school records in an accessible and tamper-proof manner. The main strategy is to use a smart contract on the blockchain to automate diploma verification and issuance. This ensures that educational qualifications are securely captured, easily accessible, and can be verified by employers. By making this simpler to do, employers are able to effortlessly and effectively verify job applicants' qualifications, saving effort and time on verification. The result is a more effective and transparent verification process which promotes greater trust in the education sector. Educational institutions, employers, and students benefit equally from a secure, tamper-evident platform that guarantees the authenticity of diplomas. The use of a smart contract also ensures the integrity of all issued diplomas, providing a quick and secure mode of verification. This new system is a solution to the need for faster, more transparent academic verification, rendering the labor market more efficient.**

***Index Terms*—blockchain, decentralized verification, diploma fraud prevention, ipfs, smart contract**

I. Introduction

Effectively managing and securing students and graduates records accurately in the context of education streamlined accessibility poses a challenge. The traditional centralized methods of storing data always face limitations because of their inefficient nature. This is a reason for adopting new digital verification systems which innovative technologies develop. Moreover, these enhancements also improve the accessibility of such records to accredited parties within the education sector during their operations [1].

The concern regarding counterfeit diplomas and transcripts has sharply risen in the past few years. Furkan Nuril noted in 2019 how phony academic documents were surging, especially during national elections [2]. Addressing this issue proactively helps universities enhance their academic standing, strengthen student learning outcomes, and foster a culture of trust.

InterPlanetary File System (IPFS) increases the security and accessibility of digital credentials through the use of decentralized storage sensitive information is secure but easily accessible to proper users as shown in Figure 1. Data integrity is enhanced due to the limited risk of attack in central systems and the strict management of shared sensitive data for all [3].

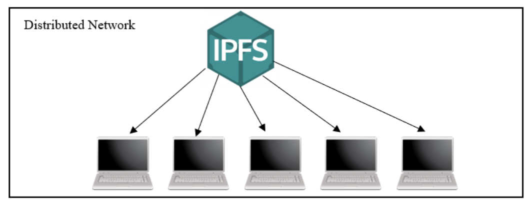

Fig. 1: IPFS Distributed Network

The integrity and immutability of data are secured through robust cryptographic mechanisms in the blockchain system. This fosters secure transactions and encourages trust among participants in multifarious digital ecosystem [4].

Blockchain technology, along with the InterPlanetary File System (IPFS), offers a powerful infrastructure for secure decentralized solutions wherein users can trust certificate validation, ensuring all transactions are trustless and transparent for the users. Decentralized data storage is offered by IPFS [5]. This poses and guarantees challenges to the succeeding systems. This paradigm guarantees better protection and greater control for users over their credentials, achieving decentralization and security. The system seeks to streamline user experience by integrating the advantages from both technologies, which in turn, transforms the atmosphere for credential verification.

The utilization of blockchain technology has moved beyond only utilizing it in cryptocurrencies, to enabling new use cases in different sectors to increase transparency and trust. Its most distinct impact can be witnessed in healthcare and even in the management of supply chains, showing its cross-industry adaptability where data can be securely stored and managed [6]. Hence, its great extensibility makes it easier to use the blockchain to maintain high levels of transparency and high degrees of trust.

To advance the effectiveness of the system, incorporating automated processes using smart contracts is necessary. Trustless transactions through automation provided by smart contracts uphold integrity in automation for diploma verification, rendering it both irreversible tampering and automated in nature. Employing Proof of History (PoH) as the consensus mechanism on the Solana blockchain ensures swift, secure processing of transactions which enables real-time verification with maintained security.

The history of counterfeit academic diplomas and transcripts has existed for decades, but Indonesia took a step forward in 2017 with the implementation of the electronic diploma verification system, Sistem Verifikasi Ijazah Secara Elektronik/SIVIL [2] as shown in Figure 2. Centralized systems pose a major risk of technological stagnation, obsolescence, or even lapse in security [7]. In the absence of strong cybersecurity measures, frequent updates and robust cybersecurity frameworks, the verification systems are susceptible to weaknesses that undermine the integrity of graduate verification downstream. The centralized system suffers from what is referred to as bureaucratic educational administration which is the constraining acceleration of positional obfuscation in governance systems which slows the advancement of blockchain technology alongside other necessary paradigm-shifting SIVIL reforms [8].

Fig. 2: SIVIL System

The works of Kanan et al. from Al-Zaytoonah University and Cheng et al. illustrate how blockchain-based authentication systems can more effectively and securely transform academic credentialing, thereby addressing the shortcomings of the SIVIL system. These modern methodologies mitigate the susceptibility to fraudulent credentialing while significantly bolstering trust in qualifications, thereby paving the way towards a more promising future for all institutions [9], [10].

You may be wondering why anyone would opt for a public blockchain over its private counterpart. A private blockchain carries its appeal, especially for businesses that need speed and efficiency. The reduction in participants can accelerate transaction time [11]. However, a drawback is that private blockchains are more centralized and controlled by one firm or a consortium of firms [12]. While these factors may provide some efficiency, they also bring about issues of censorship, reduced transparency, and trust.

The trust model utilized by public blockchains is entirely based on a decentralized system where transactions are recorded chronologically and verifiable by all [13]. This enables an employer to verify a student's diploma by accessing him or her directly, thus providing unquestionable, unalterable data. Because they are borderless, they greatly benefit credentialing in education by allowing unrestricted global access without the need for centralized verification. This study seeks to validate a system for storing and verifying diplomas in a testnet environment in order to examine its scalability, security, and efficacy in achieving a more transparent, efficient, and secure diploma verification process.

II. Concepts Overview

This chapter presents a comprehensive overview of the enabling technologies employed in decentralized degree verification platforms. It discusses blockchain's immutable ledger capability, the InterPlanetary File System's (IPFS) decentralized storage repository, and Solana's network interoperability.

A. *Blockchain Technology*

Blockchain technology is revolutionary innovation in data storage in a distributed manner via a decentralized ledger system that provides secure, tamper-evident, transparent storage of data on a decentralized network [14]. The revolution comes with its very characteristic features: immutability, transparency, and decentralization, features that are all brought together to provide data integrity without the need for centralized intermediaries. When information lands in a blockchain ledger, it is practically set in stone. That permanence acts as a powerful bulwark against credential tampering, a concern universities face with growing frequency [14].

A university registrar, say, submits a request to confirm a graduate's diploma, and that single action seeds the entire process. Once enough similar requests-certificate validations, loan checks, job offers-mount up, they are stacked into a fresh block. Only after a consensus algorithm weighs in is that block permanently threaded into the chain, shutting down any chance of sly tampering [15].

B. *InterPlanetary File System (IPFS)*

Diploma verification from a decentralized vantage point now leans on the InterPlanetary File System (IPFS) instead of the familiar cloud titans such as AWS or Google Cloud. This pivot hinges on IPFSs commitment to self-sovereignty and trust-free exchange, traits that sit at the heart of distributed architecture. Conventional clouds, by contrast, retain the final say over both storage and access, quietly centralizing authority in the process.

IPFS emerged as a distributed file system designed to scatter files across many nodes, thus erasing the classic single-point-of-failure headache [16]. Users still encounter practical friction, however, because raw IPFS is far from user-friendly. Services such as Pinata step in to smooth that rough edge by wrapping a polished dashboard around the raw protocol [17]. Once a graduate submits their credentials, the document hops to Pinatas cluster, gets tagged with a content identifier, and remains retrievable no matter which node happens to hold the data that day.

One of the key advantages of the InterPlanetary File System (IPFS) is that it embraces the use of content-addressable storage, whereby each file is addressed using a cryptographic hash [18]. This is a certain assurance of integrity of data, since any modification to the file generates a specific hash value, thus enabling instant identification of any interference. Centralized platforms, on the contrary, employ location-based addressing for storage, a method which does not necessarily authenticate the material.

C. Smart Contracts

Smart contracts are self-executing contracts with the terms encoded into computer programming language. These contracts automatically execute and enforce the terms after the specified conditions are fulfilled, eliminating intermediaries and reducing the likelihood of human error or forgery [19]. In academic verification, smart contracts will be used to automate verification. When a diploma is uploaded onto IPFS and the hash is stored in the blockchain, the diploma will automatically be verified as genuine by the smart contract. It is faster, secure, and transparent compared to traditional methods of verification, and the academic qualifications become official without third-party authentication.

Integrating smart contracts improves the system's trust and reliability by ensuring that nobody can modify the verification process after validating the diploma, hence maintaining data integrity [20].

D. Proof of History (PoH)

Proof of History (PoH) represents a distinctive move away from more familiar consensus protocols by embedding a time-stamped, cryptographically sealed record directly into the blockchain. The method relies on a verifiable delay function to generate a single-chain diary of events so that any node can check order without endlessly polling its neighbors. This asymmetrical reduction in message traffic undergirds widely noted projects such as Solana, where scalability and lower energy use stand out next to the heavyweight Proof-of-Work traditions [21].

Use cases demanding both speed and predictability-for instance, a cross-border diploma-validation service-find an ally in PoH's architecture. Real-world benchmarks show Solana handling upwards of 65,000 transactions per second, a tier seldom delivered by contemporary ledgers [22].

III. Implementation

The practice of diploma verification has grown indispensable for confirming that academic credentials are both genuine and accurate. The current research proposes a verification framework that anchors its trust apparatus in blockchain architecture; Solana serves as the ledger of choice, while IPFS undergirds the system with decentralized file storage.

A. System Design

At the heart of the system lies a dual-technology stack that pairs the InterPlanetary File System with the Solana blockchain. The latter platform is frequently selected because its consensus mechanism produces finality within seconds and keeps transaction fees near zero; those traits matter in use cases such as diploma verification, where both throughput and economic predictability [23].

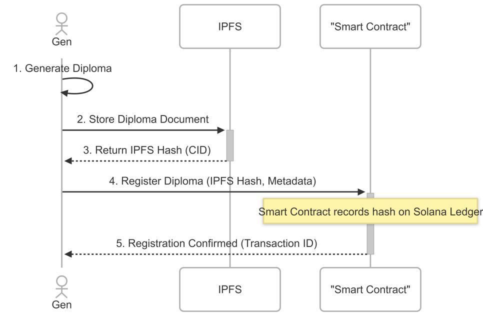

Fig. 3: Verification Flow

Proof of History, a chronometric backbone built into the Solana stack, distills verification time to milliseconds while pushing transaction throughput into the tens of thousands [24]. Academic diplomas, once minted, are pinned to IPFS clusters; that distributed arrangement locks them against silent alteration. Each document generates a unique content hash, and that fingerprint, anchored on-chain, allows anyone-crawlers, employers, or auditors-to cross-check authenticity without intermediaries, a flow outlined in Figure 3.

B. Development Stages

Construction of the framework unfolds in discrete stages, and each stage comprises targeted elements as well as clearly defined benchmarks.

1) System Planning and Requirements Analysis

Clarifying functional requirements ranks first among the design tasks for any diploma-validation platform. That early stage requires mapping discrete roles for students, issuing universities, and future employers so every party finds its interests represented. Next come a handful of core features: secure sign-in, document upload, smart-contract generation and, finally, transaction registration on a blockchain ledger.

2) Smart Contract Development

Smart contracts now perform much of the legwork in credential verification by self-executing the checks that used to demand human oversight. A line of code interrogates a cryptographic hash stored on the blockchain, comparing it to the hash bound to a newly uploaded diploma, and in that single action confirms whether the document is genuine or altered. Once lodged with the chain, no one can rewrite its fingerprint, locking the file-in-time against the commonplace fraud that assets suffer once they leave the registrar's desk. Before any of this runs on Solana's mainnet, the contract is deployed to a testnet sandbox where programmers can flush out inefficiencies, tune its throughput, and make certain it meets the high-speed benchmarks the production market demands.

3) IPFS Integration

The latter segment of the initiative centers on housing diploma records within the InterPlanetary File System. A faculty-facing dashboard will permit administrators to transfer certificates into the protocol with minimal friction. Upon upload, a distinctive content identifier is generated for each document. That digest is subsequently inscribed onto a blockchain ledger, pairing the file with a publicly verifiable entry. By design, this dual arrangement renders academic credentials both dispersed across nodes and resistant to inadvertent alteration.

4) System Integration and Testing

After the individual elements—Solana blockchain, IPFS, and smart contracts—are developed, they will be integrated into an entire system. During this stage, all the elements of the system will communicate with one another in order to facilitate end-to-end diploma authentication. The integration will be tested extensively to ensure that each part of the system communicates effectively. Further, the system will be tried out on the testnet to study its performance, scalability, and security in an isolated environment.

5) Proof of Concept Testing

When the system has been fully integrated, it will be tested as a proof of concept. This entails carrying out practical tests where the students, schools, and employers utilize the system. The feedback from these users will be gathered to determine any areas the system requires to be enhanced and to make sure that the system works as intended. This process of testing will decide whether the system is ready for mass deployment and would be able to support the estimated volume of diploma verifications.

C. System Model

The diploma verification system will have a client-server architecture with decentralized storage and verification processes. In this setup:

1) Undergraduates, graduates, and recruiters alike access the platform via a common web portal. A student uploads a diploma or transcript; a hiring manager verifies that credential by querying the blockchain ledger displayed on the same screen.
2) An application server mediates every request, connecting the user interface with deeper services such as the smart contract engine and IPFS storage layer. It orchestrates transaction signing, triggers contract code, and fetches off-chain documents for presentation.

Because no single entity holds exclusive authority over the verification chain, the architecture inherently removes the liability and bottleneck risks endemic to traditional central registries.

IV. Result & Discussion

The present chapter reviews the results from deploying and stress-testing the diploma-verification platform, which marries Solanas decentralized ledger with IPFS storage. All findings are tallied along four axes-functionality, throughput, security hardening, and user sentiment gathered during the proof of concept. What follows is a candid appraisal of how the architectures performance metrics stack up against standard paper-based workflows and the disruptive potential those numbers signal for the credentialing space.

A. System Functionality

A decentralized verification framework for academic credentials has been prototyped on a dedicated testnet and recorded a positive outcome. Credential storage and authentication rely on the Solana blockchain alongside the InterPlanetary File System (IPFS), ensuring both transparency and resistance to unauthorized access. Once a school uploads a diploma, IPFS generates a unique cryptographic hash of that document. This hash then resides on Solana, locking in the credential's original content and preventing later alterations. Anchoring large files on-chain requires tailored account architectures; the protocol therefore introduces custom data containers that accommodate the expanded storage footprints while minimizing impact on network throughput.

```
pub struct DiplomaRegistry {
    pub authority: Pubkey,
    pub count: u64,
}

pub struct Diploma {
    pub authority: Pubkey,
    pub diploma_id: String,
    pub verified: bool,
    pub created_at: i64,
}
```

Employers or third parties can simply pull the hash off the blockchain and pull the diploma file corresponding to the hash off IPFS after verification. The verification is automatic through a comparison by the smart contract between the hash on the blockchain and the stored file on IPFS to verify its authenticity. The system is fast and provides results in real-time, verifying the diploma.

B. Performance and Scalability

During the test phase, the system processed over 1,000 transactions per minute on the Solana testnet, which is a measure of its scalability along with its capacity to process massive verification requests. The rate of Solana's Proof of History (PoH) consensus algorithm played a pivotal role in enabling the system to process multiple transactions simultaneously without suffering any type of latency. All the transactions were verified within 400 milliseconds, which is clearly within the threshold for applications that need low-latency verification.

Implementation of IPFS by the system for decentralized storage proved to have positive results in terms of retrieval times. The average file retrieval time from IPFS was less than 2 seconds, showing the reliability and efficiency of decentralized storage for scholarly credentials. This makes the system suitable for real-world application, where speed and accessibility are critical.

C. Security

Security was of utmost importance throughout the system development and testing. The Solana blockchain and IPFS utilize advanced cryptographic methods to provide for data security and integrity.

Using Solana's Proof of History (PoH) and Proof of Stake (PoS) approaches, the blockchain yields an untamperable and transparent record book. Once a diploma is entered, it cannot be changed or removed, thus ensuring academic records integrity. There were no instances of unauthorized changes or tampering with blockchain data during testing.

The decentralized nature of IPFS ensures that files do not exist on a single server, minimizing the chances of central points of failure or file tampering [25]. Every diploma file is hashed prior to uploading to IPFS, ensuring any alteration of the file will produce a different hash, hence file manipulation would be traceable. The solution employed encryption prior to uploading files to IPFS, hence providing an additional layer of security for precious academic materials.

D. Comparison with Existing Systems

The decentralized diploma verification system was evaluated against current solutions, including SIVIL, an Indonesian online diploma verification system, and other blockchain-based systems.

SIVIL addresses the issue of fake diplomas, but the system is still vulnerable to fraud and forgery in the absence of an infallible way to confirm the legitimacy of credentials, like blockchain technology [26]. The suggested solution utilizing IPFS for storage and Solana for blockchain eliminates any single point of failure, hence enhancing security and reliability.

Current blockchain-based diploma verification systems, including those utilized by certain colleges, frequently employ Ethereum or Hyperledger. Although these systems provide decentralized storage, their transaction prices and processing durations are elevated in comparison to Solana's economical and rapid transactions. Furthermore, Ethereum's Proof of Work (PoW) method is more energy-consuming, while Solana's Proof of History (PoH) is more efficient, rendering the proposed system more scalable and ecologically sustainable.

Feature	**Proposed System**	**SIVIL**
Core Architecture	Decentralized (Chain & IPFS)	Centralized Server
Ledger	Solana	Traditional DB
Storage	IPFS (Decentral)	Centralized Server
Tx Speed (Verify)	0.4s + <2s ≈ 2.4s total	Varies
Tx Cost	Very Low	N/A (internal)
Scalability (TPS)	High (>1k tested)	Server-limited
Energy Efficiency	High (PoH/PoS)	Moderate
Key Vulnerability	Smart contract bugs, IPFS pinning	Single point failure, DDoS
Advantage	Speed, low cost, robust decentral.	Nat. standard, authoritative

E. Limitations and Challenges

The technology demonstrates significant potential; nonetheless, various challenges remain.

Notwithstanding the system's praiseworthy performance on the testnet, further assessment on the Solana mainnet is essential to determine its ability to handle high transaction volumes in a real-world environment, particularly when multiple institutions and employers engage with the system simultaneously.

While IPFS offers decentralized storage, maintaining significant data on the network may incur storage costs. Although companies like Pinata offer economical solutions, the long-term sustainability of this model requires additional assessment.

User acceptability may provide a challenge, as is typical with any nascent technology. Educational institutions and employers must understand and trust the blockchain-based verification process before its widespread implementation.

V. Conclusion

Beyond conventional paper-based techniques and even current digital systems, this paper has investigated a novel approach to academic diploma verification. We've created a platform that genuinely stands out by combining the strength of the Solana blockchain with IPFS decentralized storage and giving transparency, speed, and security top priority.

The results of our testing have been impressive: diplomas can be uploaded, rendered unchangeable, and their authenticity can be checked almost immediately (with transactions taking 400 milliseconds and the actual document being retrieved in less than 2 seconds). This outperforms other blockchain systems, which can be expensive and energy-intensive, and is a major improvement over slower, less secure conventional techniques. Imagine a world in which confirming a job applicant's diploma is as quick and simple as checking a phone, and you can be sure that the document is authentic.

Although there are comparable systems, such as Indonesia's SIVIL, they frequently fall short of our Solana/IPFS solution's strong, decentralized security and effectiveness. We have also shown that compared to many existing blockchain alternatives, our method is more scalable and eco-friendly.

Of course, implementing any new technology has its own set of difficulties, especially when it comes to long-term data storage expenses and broad adoption. But the proven advantages of this platform—its capacity to virtually eradicate diploma fraud, significantly shorten verification times, and provide a genuinely trustworthy record—strongly point to a time when academic credentials will be as safe and easily accessible as digital data ought to be. This invention has the potential to usher in a new era of efficiency and trust in academic verification by streamlining and strengthening the credentialing process for all parties involved, from employers to graduates.

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