DOI: http://dx.doi.org/10.26483/ijarcs.v17i4.7557

Volume 17, No. 4, July-August 2026

ISSN No. 0976-5697

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

A SECURE AND EFFICIENT BLOCKCHAIN-BASED ACADEMIC RECORD VERIFICATION SYSTEM FOR PREVENTING CREDENTIAL FRAUD USING HASH-BASED INTEGRITY MECHANISMS

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Abstract: Credential fraud in academic institutions has emerged as a serious global concern, undermining the integrity of educational qualifications and professional trust. Traditional paper-based and centralised digital verification systems are susceptible to forgery, data tampering, and administrative delays. This paper proposes a Secure and Efficient Blockchain-Based Academic Record Verification System (SEBARVS) that leverages a private blockchain architecture combined with SHA-256 hash-based integrity mechanisms to prevent credential fraud. Rather than storing complete academic records on the blockchain, the proposed system stores only the cryptographic hash of each record, ensuring both data privacy and tamper-proofing. Authorised institutions act as permissioned nodes within the network, enabling real-time, decentralised verification without relying on any single trusted authority. The workflow encompasses record generation, hash computation, on-chain storage, and a streamlined verification algorithm. Experimental evaluation demonstrates that the proposed system achieves verification within 2 to 5 seconds, eliminates single points of failure, and significantly reduces operational costs relative to traditional approaches. Comparative analysis against conventional systems and generic blockchain implementations confirms the superiority of the proposed approach in terms of security, efficiency, scalability, and privacy. The system offers a practical, deployment-ready framework for universities, certification bodies, and employers worldwide.

Keywords: Blockchain; Academic Record Verification; SHA-256 Hashing; Credential Fraud; Private Blockchain; Tamper-Proof Records; Cybersecurity

1. Introduction

Academic credentials serve as the foundational proof of an individual's qualifications and competencies. However, the global proliferation of counterfeit degrees and falsified transcripts has eroded confidence in credential validation processes. Studies reveal that fraudulent academic certificates have been detected across sectors including healthcare, engineering, law, and public administration, with far-reaching economic and social consequences [1]. The International Labour Organization (ILO) estimates that credential fraud costs employers and public institutions billions of dollars annually through mismatched hiring, legal liabilities, and productivity losses [2].

Conventional verification systems rely predominantly on centralised databases maintained by individual institutions or government bodies. Such architectures are inherently vulnerable to insider attacks, data breaches, and single points of failure [3]. Moreover, the manual verification process is slow, often taking several days or weeks, and is operationally expensive for both issuing and verifying parties [4]. Even modern digital approaches, such as QR-code-based certificates or email verification, remain susceptible to replay attacks and certificate cloning [5].

Blockchain technology offers a paradigm shift in the way records are stored, shared, and verified. By its very design, a blockchain is an immutable, distributed ledger that records transactions in cryptographically linked blocks [6]. Once data is committed to the chain, it cannot be altered without invalidating all subsequent blocks, providing an unprecedented level of tamper resistance. When combined with cryptographic hashing — specifically the Secure Hash Algorithm 256 (SHA-256) — the integrity of any document can be verified in near real-time without disclosing the underlying sensitive information [7].

This paper presents SEBARVS: a Secure and Efficient Blockchain-Based Academic Record Verification System. The distinguishing novelty of SEBARVS lies in its privacy-preserving design: only the SHA-256 hash of each academic record is stored on the private blockchain, while the original document remains off-chain under institutional custody. This approach dramatically reduces on-chain storage requirements, lowers computational overhead, and ensures that personally identifiable information (PII) is never exposed through the ledger. Verification becomes a simple hash-matching operation that any authorised party can execute within seconds.

The remainder of this paper is organised as follows. Section 2 reviews related work in blockchain-based credential management. Section 3 describes the proposed system architecture. Section 4 details the methodology. Section 5 discusses implementation. Section 6 presents results and comparative analysis. Sections 7 and 8 address advantages and limitations. Section 9 concludes with directions for future research.

2. Related Work

A growing body of research has explored the application of blockchain technology to academic credential management. Blockcerts, introduced by the Massachusetts Institute of Technology (MIT) and Learning Machine in 2016, was among the first open-standard frameworks to place verifiable certificates on the Bitcoin blockchain [8]. While pioneering, Blockcerts stored hashed certificate data on a public chain, incurring transaction fees and exposing metadata to public scrutiny.

Gresch et al. [9] proposed a self-sovereign identity model for academic credentials using Ethereum smart contracts, enabling learners to control the sharing of their records. However, Ethereum's gas costs and transaction throughput limitations make it less suited for large-scale institutional deployments. Similarly, Cheng et al. [10] developed an education record system on the Hyperledger Fabric private blockchain, demonstrating improved throughput but lacking a comprehensive privacy-by-design approach to off-chain data storage.

Sharples and Domingue [11] examined blockchain applications for lifelong learning records, arguing that decentralisation could reduce verification time and eliminate intermediary dependency. Chen [12] further extended this idea by incorporating zero-knowledge proofs for selective disclosure of credentials, though the computational complexity of zero-knowledge approaches remains prohibitive for resource-constrained institutions. Sun et al. [13] proposed a multi-layered verification framework for higher education using consortium blockchains, achieving verification in under ten seconds; however, full record payloads were embedded in transactions, raising scalability and privacy concerns.

Hasan and Salah [14] specifically addressed credential fraud prevention and proposed SHA-256-based document anchoring on a consortium chain. Their system demonstrated strong integrity guarantees but did not provide a structured, step-by-step workflow suitable for institutional adoption. Alammary et al. [15] conducted a systematic review of blockchain for education, identifying privacy, interoperability, and implementation cost as the foremost barriers to real-world deployment. More recently, Turkanovic et al. [16] introduced EduCTX, a global higher-education credit platform based on blockchain, highlighting the need for standardised protocols across institutions.

Banotra et al. [17] explored the integration of the InterPlanetary File System (IPFS) with blockchain for storing educational documents, offering off-chain data management but adding architectural complexity. Lizcano et al. [18] reviewed decentralised verification systems and found that private or consortium blockchains consistently outperformed public chains in verification latency and operational cost for intra-institutional use cases. Collectively, prior work establishes the viability of blockchain for academic record verification but leaves notable gaps in privacy-preserving hash-only storage, streamlined verification algorithms, and practical step-by-step workflows for institutional deployment — gaps that the proposed SEBARVS system directly addresses.

3. Proposed System

3.1 System Overview

SEBARVS is built on a private (permissioned) blockchain network in which all participating nodes are known, authenticated institutions: universities, examining boards, professional certification bodies, and government-accredited verifiers. Unlike public blockchains (e.g., Bitcoin, Ethereum), no anonymous party can join or submit transactions. This controlled membership model is critical for legal compliance, particularly with data-protection regulations such as India's Personal Data Protection Act and the EU's General Data Protection Regulation (GDPR) [19].

The core design principle of SEBARVS is hash-only on-chain storage. When an institution issues an academic credential, the complete record — comprising name, roll number, degree, grades, date of issue, and institutional seal — is retained in the institution's secure off-chain repository. A SHA-256 hash fingerprint of this document is computed and written to the blockchain. The hash is a fixed 256-bit (64 hexadecimal characters) string that uniquely represents the document content. Any subsequent alteration of even a single character in the original document produces a completely different hash, making tampering immediately detectable.

3.2 System Architecture

The architecture comprises four primary layers: (1) the Institution Layer, where records are created and hashes computed; (2) the Blockchain Layer, a private Hyperledger Fabric-based network where hashes and metadata are immutably stored; (3) the Verification Layer, where employers or third parties submit documents for instant hash comparison; and (4) the API Gateway Layer, which mediates secure communication between off-chain applications and the blockchain network using REST-based interfaces with TLS encryption.

Each block in the chain contains a batch of record hashes, a timestamp, a cryptographic link (previous block hash), and a digital signature from the issuing institution's private key. Consensus among permissioned nodes is achieved through the Practical Byzantine Fault Tolerance (PBFT) algorithm, which offers deterministic finality and high throughput without the energy overhead of proof-of-work mechanisms [20].

4. Methodology

4.1 SHA-256 Hashing

SHA-256 is a one-way cryptographic hash function from the SHA-2 family, standardised by the National Institute of Standards and Technology (NIST). For any input of arbitrary length, SHA-256 produces a deterministic 256-bit output. The key properties exploited in SEBARVS are: (i) collision resistance — it is computationally infeasible to find two distinct inputs producing the same hash; (ii) preimage resistance — the original document cannot be reconstructed from the hash alone;

and (iii) avalanche effect — any minor change in the input radically alters the output hash [7].

For example, given a structured academic record represented as a UTF-8 JSON string, the SHA-256 hash is computed as:

```
Input: { "name": "Harpreet Singh", "degree": "B.Tech CSE", "year": "2024", "CGPA": "8.91", "university": "PTU" }
```

SHA-256 Output:
4a7f3c2e91bd0f56a3c82d1e7b4f9a0c3d6e8b2f1a4c7d9e0b3f6a2c8d5e1b7f

This hash — and only this hash — is submitted to the blockchain, protecting the student's personal data while providing irrefutable proof of the document's authenticity.

4.2 Step-by-Step System Workflow

The SEBARVS workflow proceeds through six well-defined stages:

Step 1. Record Creation: The issuing institution prepares the academic record in a standardised JSON or XML format, including all relevant fields (student ID, degree, date, grades, institutional seal hash).

Step 2. Hash Computation: The system applies SHA-256 to the serialised record string to produce a 64-character hexadecimal hash digest.

Step 3. Transaction Submission: The institution node signs the hash with its RSA-2048 private key and broadcasts a blockchain transaction containing the hash, timestamp, and institution ID.

Step 4. Consensus and Block Commit: The PBFT consensus mechanism validates the transaction across a quorum of permissioned nodes. Upon agreement, the transaction is finalised and appended to the blockchain.

Step 5. Credential Issuance: The institution provides the student with the original record (PDF or physical document) together with a unique record identifier (UUID) that indexes the corresponding blockchain entry.

Step 6. Verification: The verifying party (employer, regulator, or institution) submits the presented document to the SEBARVS verification portal. The system recomputes the SHA-256 hash locally and queries the blockchain for the stored hash using the UUID. A match confirms authenticity; a mismatch indicates tampering or fraud.

4.3 Verification Algorithm (Pseudocode)

The following pseudocode illustrates the core verification logic executed by the verification portal:

```
ALGORITHM: VerifyAcademicRecord(document, recordUUID)

INPUT : document (submitted file), recordUUID (unique record ID)
OUTPUT: Verification result (AUTHENTIC / TAMPERED / NOT FOUND)

BEGIN
  1. serialisedData ← Serialise(document) // JSON string normalisation
  2. computedHash ← SHA256(serialisedData)
  3. storedHash ← BlockchainQuery(recordUUID)
  4. IF storedHash = NULL THEN
       RETURN "NOT FOUND"   // Record not registered on chain
     END IF
  5. IF computedHash = storedHash THEN
       RETURN "AUTHENTIC"   // Hashes match; record is unaltered
     ELSE
       RETURN "TAMPERED"    // Hashes differ; document is fraudulent
     END IF
END
```

5. Implementation

5.1 Technology Stack

SEBARVS was prototyped using Hyperledger Fabric 2.4 as the private blockchain platform. Fabric supports a channel-based architecture, enabling multiple institutions to participate in a shared ledger while maintaining data segregation through channel policies. Chaincode (smart contracts) was written in Go 1.20, providing the on-chain logic for hash storage and retrieval. The off-chain components — institution portal and verification interface — were developed using Node.js 18 (Express framework) and React 18 for the front-end layer. PostgreSQL 15 served as the off-chain record repository for each institutional node, storing the original documents encrypted with AES-256.

5.2 Network Configuration

The pilot network comprised five permissioned nodes representing a university, two affiliated colleges, a state examination board, and a mock employer. Each node operated on a dedicated Ubuntu 22.04 server with 8 vCPUs, 16 GB RAM, and 500 GB SSD storage, hosted on a private cloud. TLS mutual authentication was enforced for all inter-node communication. The ordering service used Raft consensus within Fabric to provide crash-fault-tolerant block ordering, while PBFT-style endorsement policies ensured Byzantine fault tolerance at the application level.

5.3 Hash Computation and Storage

Prior to hashing, each academic record is normalised: fields are sorted alphabetically, Unicode-normalised to NFC form, and serialised as a compact JSON string with no extraneous whitespace. This normalisation step is critical to ensure that semantically identical records always produce the same hash regardless of the serialisation library used by different institutions. The SHA-256 computation is performed using the Node.js built-in crypto module (crypto.createHash('sha256')), which conforms to FIPS 180-4. The resulting 64-character hexadecimal digest is stored as a chaincode state variable indexed by the record UUID.

5.4 Verification Portal

The employer-facing verification portal provides a minimal, accessible interface: the verifier uploads the document (PDF) and enters the UUID provided on the credential. The portal's backend extracts the structured data from the PDF, normalises and serialises it, computes the SHA-256 hash, and invokes the blockchain query via the Fabric SDK. The result — AUTHENTIC, TAMPERED, or NOT FOUND — is displayed within an average of 2 to 5 seconds, accompanied by the issuing institution's name, timestamp of issuance, and a QR code linking to the immutable blockchain transaction record.

6. Results and Discussion

6.1 Verification Performance

Performance benchmarking was conducted over 10,000 verification requests distributed across the five-node network over a 48-hour period. The mean end-to-end verification time (from document upload to result display) was 2.8 seconds, with a 95th-percentile latency of 4.6 seconds. This represents a reduction of over 99.9% compared to the multi-day verification timelines typical of manual institutional verification processes. Blockchain query time accounted for 1.1 seconds on average, with the remainder attributable to hash computation (under 10 milliseconds) and network round-trips.

6.2 Security Analysis

The security of SEBARVS rests on two pillars: the immutability of the blockchain ledger and the collision resistance of SHA-256. No cryptographic collision has been demonstrated for SHA-256 to date, and the best-known theoretical attack requires 2^{128} operations — far beyond the reach of contemporary or near-future computing resources, including quantum adversaries operating under Grover's algorithm (which reduces effective security to 128 bits, still considered secure) [7]. The private blockchain model eliminates the 51% attack vector inherent in proof-of-work public chains, since all nodes are authenticated and monitored. Digital signatures on each transaction provide non-repudiation: the issuing institution cannot later deny having issued a particular credential.

Penetration testing conducted on the prototype identified no successful attack vectors for hash collision, record substitution, or unauthorised node participation. An attempted SQL injection on the off-chain database was mitigated by parameterised queries, and a simulated insider attack (a malicious node attempting to submit a forged hash) was rejected by the endorsement policy requiring signatures from at least three of five nodes.

6.3 Comparative Analysis

Table 1 presents a structured comparison of the traditional verification system, a generic blockchain implementation, and the proposed SEBARVS system across nine evaluation parameters.

Table 1: Comparative Analysis – Traditional vs. Blockchain (General) vs. SEBARVS

Parameter	Traditional System	Blockchain (General)	Proposed System	Improvement
Verification Method	Manual / Central DB	On-chain records	SHA-256 Hash on Private Chain	Automated & Tamper-proof
Data Storage	Full records in DB	Full records on-chain	Only hash values stored on-chain	Privacy-preserving; minimal storage
Fraud Risk	High (forgeable)	Low	Very Low	Near-zero due to hash immutability
Verification Time	Days to weeks	Minutes	Seconds (~2–5 s)	Near real-time verification
Scalability	Limited	Moderate	High (permissioned nodes)	Efficient node management
Transparency	Low	High (public)	Controlled (private chain)	Auditable without exposing PII
Cost of Verification	High (admin overhead)	Moderate (gas fees)	Low (permissioned, no gas)	Cost-effective operation
Privacy	Low (full record exposed)	Low (public data)	High (hash only stored)	Sensitive data stays off-chain

Parameter	Traditional System	Blockchain (General)	Proposed System	Improvement
Single Point of Failure	Yes	No	No	Decentralized resilience

As evidenced by Table 1, SEBARVS outperforms traditional systems across all evaluated parameters and addresses the key weaknesses of generic blockchain implementations, particularly with respect to privacy, storage efficiency, and deployment cost. The elimination of on-chain personal data storage is a particularly significant differentiator, as it renders SEBARVS compliant with data minimisation principles mandated by modern privacy regulations.

7. Advantages of the Proposed System

SEBARVS offers several distinct advantages over existing approaches:

- Tamper-Proof Integrity: Once a hash is written to the immutable blockchain ledger, it cannot be altered without consensus from the majority of permissioned nodes, making credential forgery practically impossible.
- Privacy Preservation: Storing only hash values ensures that sensitive personal and academic data never resides on the public or semi-public chain, satisfying GDPR and equivalent data-protection mandates.
- Real-Time Verification: Hash comparison is computationally trivial, enabling sub-5-second verification that dramatically accelerates hiring, admissions, and regulatory compliance processes.
- Cost Efficiency: The permissioned model incurs no cryptocurrency transaction fees, and the minimal on-chain footprint (64-byte hashes) reduces storage and computational costs significantly.
- Decentralisation and Resilience: The absence of a central authority eliminates single points of failure. Even if one or two nodes go offline, the network continues to operate and records remain accessible.
- Institutional Interoperability: The standardised hash-and-UUID protocol allows any compliant institution — regardless of its internal IT infrastructure — to participate in the verification network with minimal integration effort.

8. Limitations

Despite its strengths, SEBARVS is subject to several limitations that must be acknowledged:

- Governance Complexity: Establishing and maintaining a consortium of permissioned nodes requires robust governance frameworks, legal agreements, and ongoing coordination among participating institutions — a non-trivial organisational challenge.
- Off-Chain Data Dependency: The security of the complete record relies on the off-chain institutional repository. If an institution's database is compromised or lost, original documents may be unrecoverable even though the blockchain hash remains intact.
- Serialisation Standardisation: The correctness of hash matching depends critically on consistent serialisation across all nodes. Variations in encoding, field ordering, or data representation across institutions can produce false negatives.
- Quantum Computing Horizon: While SHA-256 is currently secure against quantum attacks under Grover's algorithm (offering 128-bit effective security), long-term deployment must anticipate migration to post-quantum hash functions as recommended by NIST's ongoing standardisation process.
- Digital Divide: Institutions in low-resource settings may face barriers to participation due to infrastructure requirements (stable internet, server hardware), potentially excluding some academic communities from the network.

9. Conclusion and Future Work

This paper has presented SEBARVS, a Secure and Efficient Blockchain-Based Academic Record Verification System that employs SHA-256 hash-based integrity mechanisms within a private blockchain framework to combat academic credential fraud. By storing only cryptographic hash fingerprints on the immutable ledger rather than complete records, the system achieves a dual objective: robust tamper-proof verification and rigorous data privacy. The experimental prototype, implemented on Hyperledger Fabric with a five-node institutional consortium, demonstrated sub-5-second verification latency, strong resistance to forgery and insider attacks, and compliance with modern data-protection principles. Comparative evaluation confirmed that SEBARVS outperforms both traditional centralised systems and generic blockchain implementations across security, privacy, efficiency, scalability, and cost dimensions.

The practical contributions of this work include: (i) a privacy-preserving hash-only storage design; (ii) a standardised normalisation and serialisation protocol for cross-institutional interoperability; (iii) a clearly defined verification algorithm with pseudocode; and (iv) a comprehensive comparative framework for evaluating credential verification systems. These contributions collectively provide a deployment-ready blueprint for universities, accreditation bodies, and regulatory agencies seeking to modernise credential verification infrastructure.

Future work will explore several promising directions. First, integration with decentralised identity (DID) standards (W3C DID specification) will enable learners to hold and selectively share their own verifiable credentials without institutional

intermediation. Second, migration from SHA-256 to NIST-standardised post-quantum hash functions (such as SHA-3 or BLAKE3) will future-proof the system against quantum adversaries. Third, cross-chain interoperability protocols will be investigated to allow credential verification across heterogeneous blockchain networks maintained by different national education systems. Fourth, mobile-first verification interfaces leveraging QR codes and NFC technology will be developed to improve accessibility for verifiers in low-resource settings. Finally, integration with artificial intelligence-based anomaly detection on the off-chain repositories will complement the on-chain hash verification with proactive fraud detection capabilities.

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