

Token-based e-Learning System Harnessing Hyperledger Besu

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Abstract—Traditional online education systems often emphasize digital certification over robust, universally accepted evaluation procedures. This study introduces a novel e-learning system using Hyperledger Besu blockchain technology to enhance and secure educational processes. The system employs tokenization and NFTs to represent and validate lifelong learning achievements through smart contracts, ensuring transparency and immutability. Performance benchmarks with Hyperledger Caliper demonstrate the system’s efficiency and highlight optimization areas. This study showcases blockchain’s practical applications in education, providing a scalable and secure framework for academic credentialing and assessment.

Index Terms—E-Learning, Hyperledger Besu, Hyperledger Caliper, NFT, Smart Contract.

I. INTRODUCTION

In conventional online education, certification involves a methodical verification process overseen by educational institutions or certifying bodies, which set curriculum standards and evaluation protocols. However, the rise of online institutes has led to counterfeit certifications [1], and the lack of transparency and rigorous evaluation prevents these systems from gaining academic recognition [2].

Hyperledger, a Linux Foundation project, advances blockchain technologies, including Hyperledger Besu, designed for enterprise use in public and private networks. Besu supports Ethereum protocols and is compatible with the Ethereum Virtual Machine (EVM) [3], making it ideal for building blockchain applications. This study proposes using Hyperledger Besu to authenticate online education services, enhancing reliability and transparency.

Traditional online education certification faces issues like fraud and difficulty verifying [4] authenticity. Prior blockchain-based studies for educational certificates encountered high costs and network participation challenges. Although NFTs have been proposed for credentials, they lack a widespread maintenance system [5].

The proposed system addresses these issues by operating on both public and private blockchains, accommodating various [6] institutional needs. It follows the Token Taxonomy Framework (TTF) for standardized token generation and extends NFTs to a broader educational context, enhancing their utility and value. [7]

II. METHODOLOGY

A. Token Based e-Learning

The proposed system merges conventional e-learning with token-based innovations to create a transformative educational approach. Underpinned by blockchain technology, it offers a secure framework that enriches the educational journey, as illustrated in Fig. 1.

In this ecosystem, educational institutions orchestrate course development and delivery. Educators curate curriculum content, including materials, evaluation criteria, and guidelines. Learners engage with courses, participate in evaluations, and earn recognized certifications.

The blockchain layer introduces Learning Tokens, digital representations of academic progress. Scholars’ achievements are quantified and stored in digital wallets, serving as a currency of academic merit. Tokenized guidelines ensure transparency and standardization, with smart contracts automating educational processes. Learning Tokens are minted and transferred to scholars’ wallets in real-time as they reach course milestones, providing immediate validation and feedback.

Upon course completion, the digital wallet reflects a scholar’s total efforts and skills, offering a dynamic transcript of achievements. Backed by blockchain, this record provides verifiable evidence of proficiency. The traditional certificate is reimaged as a secure, portable, and digital validation of educational success.

This token-based e-learning system revolutionizes the validation, evaluation, and recognition of learning, aligning with our digital-first society and enhancing the recognition of educational achievements.

B. Feasibility and Security Analysis

Hyperledger Besu, an enterprise-grade Ethereum client, enhances a token-based e-learning system with robust security through Proof of Authority (PoA) and Proof of Work (PoW) consensus mechanisms, ensuring trustworthiness and fraud reduction in permissioned networks. Besu’s permission-based features control access, ensuring data privacy and compliance.

Compatible with Ethereum, Besu supports Solidity smart contracts and ERC-20/721 token standards, facilitating token creation, issuance, and management. This compatibility allows integration with external Ethereum applications, enhancing the learning ecosystem. ERC-721 NFTs provide security features

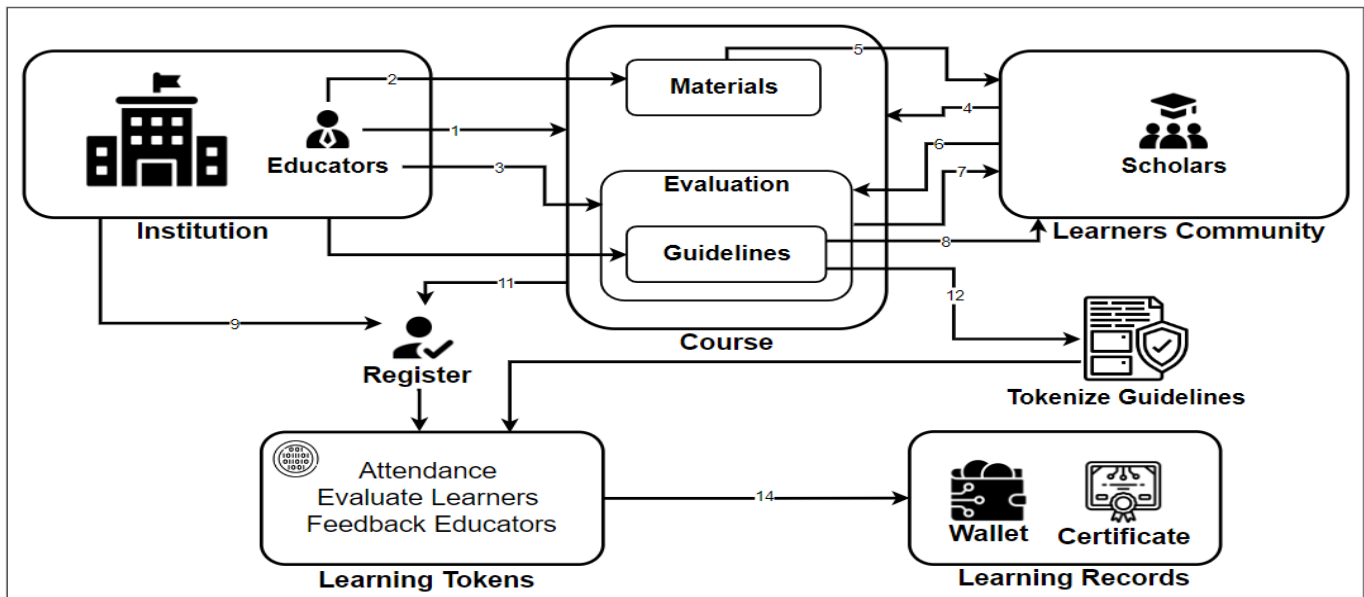


Fig. 1: Overall system of token-based e-learning

like ownership and transfer restrictions, preventing credential duplication.

Educators can issue tokens for various achievements, while learners benefit from securely recorded, verifiable, and portable accomplishments.

III. PERFORMANCE ANALYSIS

TABLE I: Benchmark test results

Operation	Send Rate (TPS)	Avg Latency (s)	Throughput (TPS)
addEducatorToInstitution	5.1	14.47	20.5
getCourseMaterials	20.3	13.15	25.3
transferEducatorToken	3.5	12.56	2.0

A. Performance Evaluation

Our performance analysis using Hyperledger Besu and Hyperledger Caliper tested key operations in the e-learning system. The results showed solid performance for adding educators and retrieving course materials, with good throughput and manageable latency. However, transferring educator tokens revealed lower throughput and higher complexity, indicating a need for optimization. These benchmarks provide critical insights for future improvements to the blockchain network's efficiency shown in the Table I

IV. CONCLUSION

This study implements Hyperledger Besu blockchain in e-learning to ensure educational transparency using tokenization and NFTs. Benchmarking shows scalable, secure solutions for global academic institutions. Future work will refine system implementation, enhance security for token generation, and establish seamless token lifecycle management.

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