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The Design Approach of Ethereum-based Student Achievement Record System on Private Blockchain Network

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Abstract

Blockchain transformative technology that enables secure, decentralized, and immutable transaction recording through a network of cryptographic blocks, enhancing transparency and trust without the need for a central authority or intermediaries. The Ethereum platform builds upon this foundation by facilitating the development of decentralized applications (dApps) and smart contracts, which automate processes and improve operational efficiency. In higher education, the Student Activity Credit Unit (SACU) system exemplifies the application of blockchain by managing both academic and non-academic achievements, thus promoting a holistic approach to student development and enhancing essential soft skills like leadership and teamwork. By leveraging a decentralized system built on Hyperledger Besu, the SACU ensures that student records are secure, transparent, and scalable, while providing real-time monitoring and verification of achievements. This paper evaluates the decentralized student's achevements record model, demonstrating its improvements in transparency, security, and efficiency over existing systems, ultimately preparing graduates for professional success and fostering trust in the recognition of their qualifications.

Keywords: Blockchain, Ethereum, Academis Record, Hyperledger Besu

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INTRODUCTION

Blockchain is a revolutionary technology for securely recording transactions in a decentralized and immutable manner, utilizing a chain of cryptographic blocks that ensure transparency and trust in a system managed by a network of nodes, rather than a central authority [1]. A decentralized system, like blockchain, empowers participants by eliminating the need for intermediaries, significantly enhancing security and reliability [2], [3]. Ethereum extends blockchain's capabilities by introducing a platform for developing decentralized applications (dApps) using smart contracts which automate processes without human intervention [4], [5]. Hyperledger Besu is an open-source Ethereum client that caters to enterprise needs, offering features like on-chain permissioning, privacy tools, and adherence to industry standards for interoperability, thus enabling businesses to leverage blockchain technology for secure and transparent operations [6].

In higher education, student academic achievement is enriched by both academic and non-academic activities, highlighting the importance of a holistic approach to student development. The Student Activity Credit Unit (SACU) system, used in universities like those in Indonesia, records and manages students' extracurricular engagements, crediting activities such as participation in student organizations, competitions, and community service as part of graduation requirements. This system encourages students to engage in diverse experiences that nurture soft skills like leadership, teamwork, and time management, essential for career readiness. Academic activities, including lectures and internships, complement co-curricular experiences like workshops. Recording these achievements provides a well-rounded evaluation of student capabilities, enhancing employability and ensuring institutional transparency. By integrating both academic and non-academic accomplishments, universities prepare graduates to excel in their professional and civic roles.

The a decentralized system for the Student Activity Credit Unit (SACU) emphasizes the need for security, transparency, and scalability in recording student achievements. Key system requirements include ensuring that data remains immutable and tamper-proof, which blockchain technology satisfies by creating a secure environment for storing student activities. With features like decentralized access for students, academic staff, and verifiers, the system eliminates reliance on a central authority while providing a clear view of all transactions to authorized stakeholders. The architecture integrates various components, including a web interface, a private blockchain (Hyperledger Besu), smart contracts, and decentralized storage (IPFS), to facilitate secure data processing and verification, ultimately shaping a robust and efficient solution for managing student activity records [7].

The contributions of this paper lie in its comprehensive evaluation of the decentralized SACU system compared to existing models. By highlighting significant improvements in transparency, security, efficiency, and decentralization, the paper showcases how blockchain technology enhances the integrity and accuracy of student data. The automation of verification processes through smart contracts reduces administrative burdens and accelerates operations, while the decentralized nature of the system fosters trust among users. Additionally, the successful integration of web and blockchain components, alongside real-time monitoring and activity tracking through an explorer interface, demonstrates a significant advancement in how student achievements are recorded and verified, ultimately preparing students for their professional journeys while providing a transparent assessment of their educational experiences.

The advent of smart contracts, particularly on platforms like Ethereum, allows for the automation and refinement of processes that previously required intermediaries, enhancing operational efficiency and accountability with immutable records. In higher education, the implementation of a decentralized system for the Student Activity Credit Unit (SACU) showcases these advantages, as institutions can transparently manage student achievements in a tamper-proof manner using Hyperledger Besu [8]. This innovative architecture integrates both academic and non-academic activities, promoting comprehensive student development while meeting institutional requirements, ultimately ensuring that graduates possess the necessary skills for professional success and that universities maintain trust and accountability in the recognition of achievements and qualifications.

Related Works

In addressing the challenges associated with the management of academic records, several previous studies have identified common issues such as data security, integrity, and inefficiencies in existing systems. These challenges are particularly evident in the areas of storing, managing, and authenticating student records and credentials

Han et al. (2018) [9], in their study, highlighted the inefficiencies and vulnerabilities inherent in current systems used for managing student records. The study pointed out that these systems are prone to errors and misuse, making them unreliable. The authors proposed a blockchain-based solution that could enhance the reliability and security of educational records by ensuring that once recorded, the data cannot be altered or lost, even if the issuing authority ceases operations.

Similarly, Kanan et al. (2019) [10] emphasized the need for secure and reliable records in the confirmation of educational certificates. They discussed how the current systems often fail to protect against the loss or forgery of physical documents. Their research demonstrated the potential of blockchain technology to prevent data forgery and ensure the authenticity of educational documents issued by institutions.

Huang (2020) [11] addressed the high costs, significant time consumption, and dependence on third parties associated with traditional academic credential management. The study proposed a blockchain platform as a solution to these issues, offering a more efficient and transparent verification process that reduces reliance on centralized third parties.

Further extending the discussion, Alnafrah and Mouselli (2021) [12] explored the application of blockchain in the context of academic records management in low-income countries. Their study highlighted how political and economic factors in such regions exacerbate the challenges of verifying and accrediting academic credentials. They proposed a blockchain-based solution that could reduce costs and improve the efficiency of academic records management in these environments.

Blockchain Technology

A. Technology Overview

Satoshi Nakamoto presented blockchain technology in his article 'Bitcoin: A Peer-to-Peer Electronic Cash System' that provided a solution for an immutable and decentralized way of recording transactions as early as 2008 [13], [14], [15]. This system rests on a chain of blocks, with each containing ledger entries that are linked to the previous block through cryptography. This brings structure in an otherwise unstructured system, the way lockers are used to pack luggage, and by distributing this across a network of nodes, it results in an immutable ledger that assures us that once you put stuff into these drawers they cannot be changed without consensus on all networks.

Blockchain innovation allows a trustless system, which means that a group/contact of participants can make secure transactions among themselves without trusting any central authority [16], [17]. Blockchains store records on a decentralized basis, meaning that all nodes in the network share control over it, which makes for transparent ledger and extra secure transactions [18]. These are done using consensus mechanisms to validate all transactions and maintain an incorruptible record. With the progression of blockchain technology, there also came a potential for it to be used outside financial transactions. That evolution is what led to the creation of Ethereum, a blockchain platform that makes it possible for developers all over the world to build useful, real-world projects on top of this new and exciting protocol called "blockchain." Where Bitcoin aimed primarily to support peer-to-peer digital currency transactions, Ethereum ushered in a new concept by enabling smart contracts, the self-executing programs on the blockchain.

B. Ethereum Platform

While blockchain is decentralized and immutable by nature, Ethereum elevates this by providing a platform where developers can build applications. These decentralized applications (dApps) operate autonomously, governed by smart contracts. This transforms the blockchain from a passive ledger into an interactive platform for handling complex operations. Smart contracts on the Ethereum blockchain have made it possible to automate processes that typically required intermediaries, such as financial agreements, supply chain management, and even elections. By ensuring that the code operates exactly as programmed, without downtime, censorship, or third-party interference, transactions become more reliable, fostering faster trust-building among participants on the network.

C. Decentralization and Transparency

Two defining characteristics of blockchain technology are decentralization and transparency, which both play a significant role in making it possible to trust the information held within its data structures securely [19], [20], [21]. Blockchain networks can be categorized into two main types: public and private [22], [23], [24].

- **Public blockchains** are open networks that allow anyone to participate as a node, validate transactions, and access the history of this blockchain, like Bitcoin and Ethereum.
- **Private blockchains**, are contained networks that allow only select parties to interact with the blockchain, validate transactions, or become a node. Most often, these are blockchains where enterprises want more control.

To sum up, it should be realized in which situations public blockchains are necessary to improve transparency and trustbuilding, or such requirements mix better with enterprise applications covering control-oriented use cases for letting private-blockchain technology satisfied.

Table 1. Public Vs Private Blockchain

Aspect	**Public**	**Private**
Permission	Permissionless	Permissioned
Access	Accessible to everyone	Entry by invitation
Authority	Decentralised	Can be centralised
Speed	Slow	Fast
Scalability	Hard to scale	Easy to scale
Transactions per second	Less	More
Energy Consumption	High	Low

D. Ethereum Client

Hyperledger Besu is known as a Hyperledger project by Linux Foundation and an open-source Ethereum client. The project that would become Hyperledger Besu was previously known as Pegasys Pantheon and merged with the broader initiative in 2019. Hyperledger Besu marks the first submission of a public blockchain project to Hyperledger, reflecting the clear sense among enterprises that both permissioned and public networks will play key roles in their networks. The project design and architecture decisions prioritize clean interface and modularity to become the platform of choice for open development, deployment, and integration with Hyperledger Besu [25]. Besu is designed for modularity, so the consensus implementation and other core blockchain features are cleanly isolated and easy to replace or upgrade.

Hyperledger Besu also includes a range of features that enhance its suitability for enterprise use cases:

- **On-Chain Permissioning:** This feature enables organizations to define and secure access, as well as control the actions different participants execute within a network.
- **Privacy Features:** Tools for private transactions and the creation of private smart contract instances enable individuals or organizations to handle sensitive data while maintaining control over who can access this information from the blockchain.

- **Performance and Scalability:** The architecture of the Besu client has been built from scratch to be high performance, scalable, with fast transaction throughput capability needed for an enterprise solution.
- **Modularity and Extensibility:** The modular architecture of Besu enables users to customize the system as they wish, including integrating it with various existing systems or tools.
- **Enterprise Ethereum Alliance (EEA) Compliance**: Besu adheres to the EEA specifications, ensuring interoperability with other Ethereum-based solutions and facilitating the adoption of industry standards.

Taking advantage of Hyperledger Besu, enterprises can unlock the innovative power of blockchain technology while retaining full sovereignty over their network. Using a private Besu-powered Ethereum network allows enterprises to provide transparent and secure applications to handle sensitive data and transactions.

Student's Academic Achievement In Higher Education

This section describes the student's academic achievement in academic activities in higher education.

A. Student Activity Credit Unit

The reference used for this case study is the Student Activity Credit Unit (SACU) system implemented by some universities in Indonesia. It is a platform for recording and managing of student non-academic activities over the course of their studies. How important is this system because it wants to see students embrace student activities, organizations, and even personal development outside the academic world? Students also received credits for contributing to an organization or committee that does social activities. The credits are then tabulated as part of the graduation requirements. What follows is a breakdown of the main activity categories tracked in the system.

- **Student Organization Activities:** Active participation in student organizations such as the Departmental Student Association, Student Executive Board, and other campus organizations.
- **Competitions and Contests:** Involvement in competitions at local, national, or international levels, including academic, sports, and arts competitions.
- **Training and Seminars:** Participation in trainings, workshops, and seminars aimed at self-development and improving skills outside of the academic curriculum.
- **Social Activities:** Student participation in social activities, such as community service programs, voluntary work, or other charitable activities.

Students simply select from the menu of activities and receive a set credit weight for that specific type or level of participation in the activity. The Student Activity Credit Unit system is a spirit to encourage the students to be more active in extracurricular activities, and therefore their soft skills will be good if they go up from this university for graduates such as organizational written skills ability, teamwork, leadership, time management, etc.

B. Academic Activities

Academic activities are a range of formal learning experiences that students must participate in as part of their academic journey. These activities align with the institution's goal of producing well-rounded graduates who possess both technical expertise and soft skills. Academic activities are divided into two categories: curricular activities and cocurricular activities.

Table 2. Academic Activities At State Polytechnic Of Malang

No.	Curricular	Co-Curricular
1	Lectures	Workshops / Seminars
2	Exams	Student Organizations
3	Final Project / Thesis	Conferences
4	Internships	Community Service

C. Non-Academic Activities

Non-academic activities play an important role in fostering personal growth, social skills, and general well-being among students. These activities are also recorded in the **Student Activity Credit Unit** system. Examples of non-academic activities include:

Table 3. Non-Academic Activities At State Polytechnic Of Malang

No.	Category	Examples
1	Sports	Athletic events
2	Cultural Events	Art exhibitions, music, dance
3	Volunteering	Service projects
4	Leadership Training	Communication, decision making skills

D. Importance of Recording Student Achievements

Recording both academic and non-academic activities provides several benefits:

- **Holistic Evaluation:** The comprehensive evaluation of both academic and non-academic achievements creates a balanced view of a student's capabilities.
- **Skill Development and Personal Growth:** Participating in extracurricular activities allows students to develop essential life skills such as leadership, teamwork, communication, and time management.
- **Enhanced Employability:** A strong record of both academic and non-academic achievements can significantly boost a student's employability by showcasing their versatility and motivation.

- **Institutional Accountability and Transparency:** A detailed record of student activities enables universities to assess student development and ensure transparency in how student achievements are recognized.

The Student Activity Credit Unit system, therefore, plays a critical role in shaping student's academic and personal growth, ensuring that university graduates are well-prepared to meet professional and civic responsibilities.

DESIGN OF DECENTRALIZED SYSTEM

This section explains the decentralized system for Student Activity Credit Unit recording that must be secured.

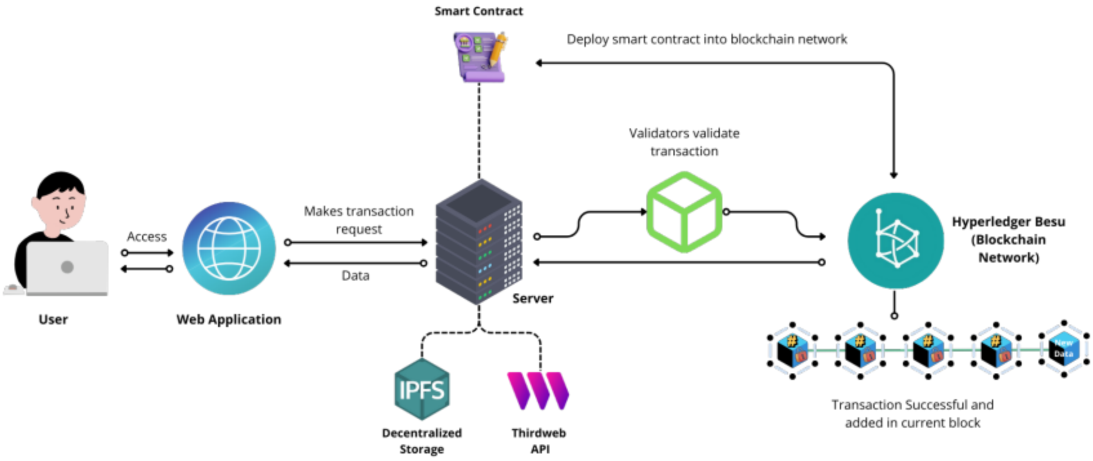
A. System Requirements

The decentralized system for Student Activity Credit Unit recording must be secure, immutable, and accessible to authorized stakeholders. The system's core requirements include:

- **Security and Immutability:** The system must ensure that student activity records cannot be tampered with once added. Blockchain technology provides immutability, making it ideal for securely storing and verifying student activities.
- **Transparency:** All transactions and data modifications should be visible to authorized parties, ensuring transparency in the validation and recording of activities.
- **Decentralized Access:** The system must be accessible to students, academic staff, and verifiers such as the Departmental Student Association and the Student Executive Board without relying on a central authority.
- **Scalability:** The system must handle increasing numbers of student records efficiently, scaling as the student population grows.

The decentralized system can be implemented on a private blockchain, such as Hyperledger Besu, which offers permissioned access while ensuring data integrity and security.

Fig. 1. System Architecture of the Decentralized SACU Recording System



B. System Architecture

The system architecture for the decentralized Student Activity Credit Unit (SACU) recording system, as illustrated in Fig. 1, integrates key components of web technologies, blockchain, decentralized storage, and cryptographic processes. This architecture ensures secure, decentralized data processing, leveraging blockchain technology for transparency and immutability.

The architecture can be broken down into the following components:

- **User Interface (UI):** Users, typically students, interact with the system via a web application. This application allows users to submit their activity records (such as participation certificates), verify their activity status, and generate proof of their submissions. The web interface acts as the primary access point for the student to the decentralized system.
- **Web Server:** The web server handles requests from the frontend (UI) and processes them by interacting with the blockchain network and decentralized storage system. It serves as a middle layer to manage the interactions between the user and the decentralized backend services like the blockchain and IPFS.

Table 4. Hardware specifications

Component	Details
Processor	Apple M2 Pro chip, 10-core
GPU	16-core
Memory	16 GB unified memory
Storage	512 GB SSD
Operating System	macOS Sonoma

- **Blockchain Network (Hyperledger Besu):** At the core of the system is a private blockchain implemented using Hyperledger Besu. This ensures that all student activity records are securely stored in an immutable ledger. The blockchain handles transactions, such as submitting activities, verifying records, and validating student submissions, with all actions being cryptographically secure. The consensus mechanism used here is IBFT (Istanbul Byzantine Fault Tolerance) to ensure reliability and security in transactions. The nodes in the network work together to maintain consensus and redundancy and it requires a minimum of 4 nodes for proper fault tolerance.

Table 5. Network specifications

Component	Details
Consensus Mechanism	IBFT (Istanbul Byzantine Fault Tolerance)
Nodes	At least 4 nodes for redundancy and fault tolerance

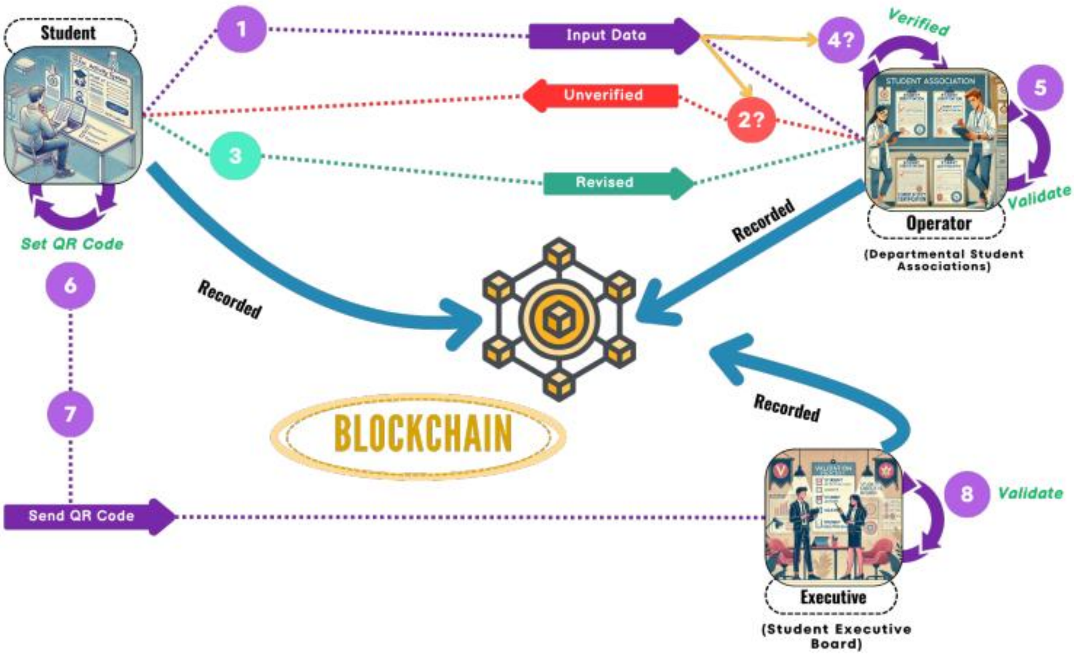
- **Smart Contracts:** Smart contracts written in Solidity run on the Hyperledger Besu blockchain. These contracts automate the process of verifying and validating student activities. They ensure that once a record is submitted, the verification process can be conducted transparently, and no central authority can manipulate the data.
- **Decentralized Storage (IPFS and Web3.storage):** Supporting documents, such as participation certificates or proof of activity, are stored off-chain using the InterPlanetary File System (IPFS). IPFS is a decentralized storage system, ensuring that evidence remains secure and accessible even if parts of the network are down.
- **Activity Data Tracking (Blockchain Ledger):** Once activities are verified and validated, they are permanently recorded in the blockchain ledger. This ensures that the student's achievements are immutable and can be audited by third parties if necessary.

This architecture ensures that the SACU system is scalable, secure, and transparent, leveraging decentralized technologies to provide an efficient solution for managing and verifying student activity records in a tamper-proof manner.

C. System Workflow

The conceptual workflow for the decentralized Student Activity Credit Unit recording system is illustrated in Figure 2.

Fig. 2. Student Activity Recording System Workflow



The steps in the workflow are as follows:

1) **Activity Submission:** Students submit their activity records, including digital evidence, via the web application.
2) **Initial Verification:** The Departmental Student Association reviews the submitted activity. If the submission meets the requirements, it is approved; otherwise, it is sent back to the student for revisions.
3) **Final Verification:** Once the revised activity meets the criteria, it is marked as verified by the Departmental Student Association.
4) **Activity Validation:** After the Departmental Student Association verifies the activity, they validate the activity to confirm its completion.

DEVELOPMENT PLAN AND EVALUATIONS

This section provides a comprehensive evaluation of the Student Activity Credit Unit system. The evaluation covers the system's functionality, performance, and security, based on specific testing scenarios and criteria defined during the development process.

A. Comparison with the Existing System

The blockchain-based Student Activity Credit Unit (SACU) system developed in this research presents significant differences compared to the current system. These differences are evident across several aspects:

- **Transparency and Trust:** The blockchain system enhances transparency by recording all SACU transactions on a distributed ledger, which can be verified by authorized parties. This increases trust in the integrity and accuracy of SACU data, as users can directly verify transactions via blockchain explorers.
- **Security and Data Manipulation Risks:** The blockchain system employs cryptographic technology to protect SACU data from unauthorized access. Changes to the data are recorded as new transactions, ensuring that data cannot be modified without detection and maintaining data integrity.
- **Efficiency and Automation:** By automating processes such as verification and validation through smart contracts, the blockchain system reduces reliance on manual processes, minimizing errors and accelerating operations. This results in decreased administrative workload and faster processing times.

Table 6 summarizes the comparison between the proposed blockchain-based system and the current SACU system at State Polytechnic of Malang:

Table 6.Comparison of sacu systems

Aspect	Existing System	Blockchain System
Transparency and Trust	Low	High
Security and Data Manipulation Risks	Low	High
Efficiency and Automation	Low	High
Decentralization	No	Yes
Storage of Participation Evidence	Centralized	Distributed (IPFS)

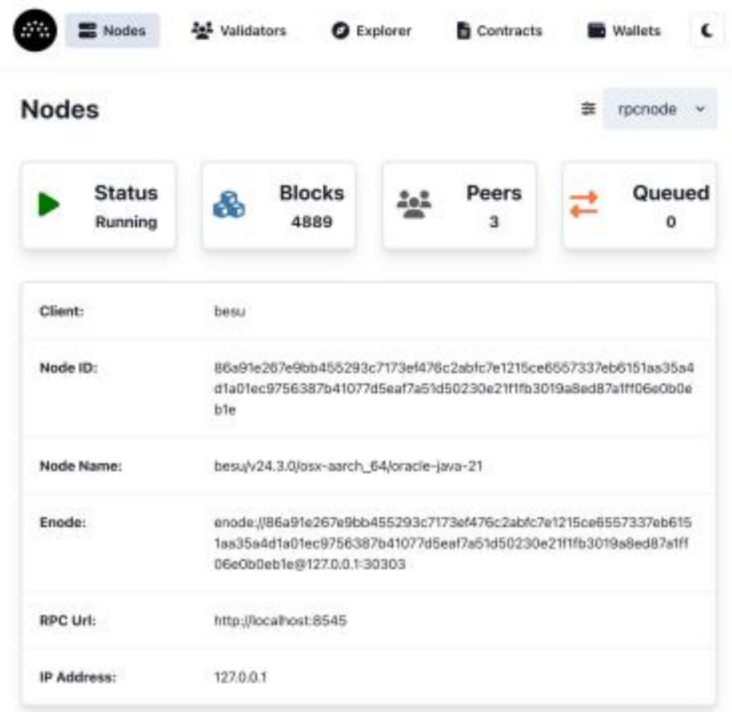
Based on this comparison, it can be concluded that the proposed blockchain-based SACU recording system offers significant improvements in transparency, security, efficiency, decentralization, and data storage compared to the existing system.

B. Integration

The web application and blockchain components have been successfully integrated, as shown by the status of the Hyperledger Besu node running in the private network. The interface displays the node's status, blocks processed, peers connected, and other key information, ensuring that the blockchain system is operational and maintaining the consensus protocol.

1) *Nodes:* The Nodes provides detailed information about the current status of each node in the blockchain network. This includes the node's client (Besu in this case), the unique node ID, node address, RPC URL, and IP address. Additionally, it displays the number of blocks processed and the number of peers connected to the network, which ensures that the node is functioning properly and contributing to the consensus protocol.

Fig. 3. Nodes Status in Blockchain Network

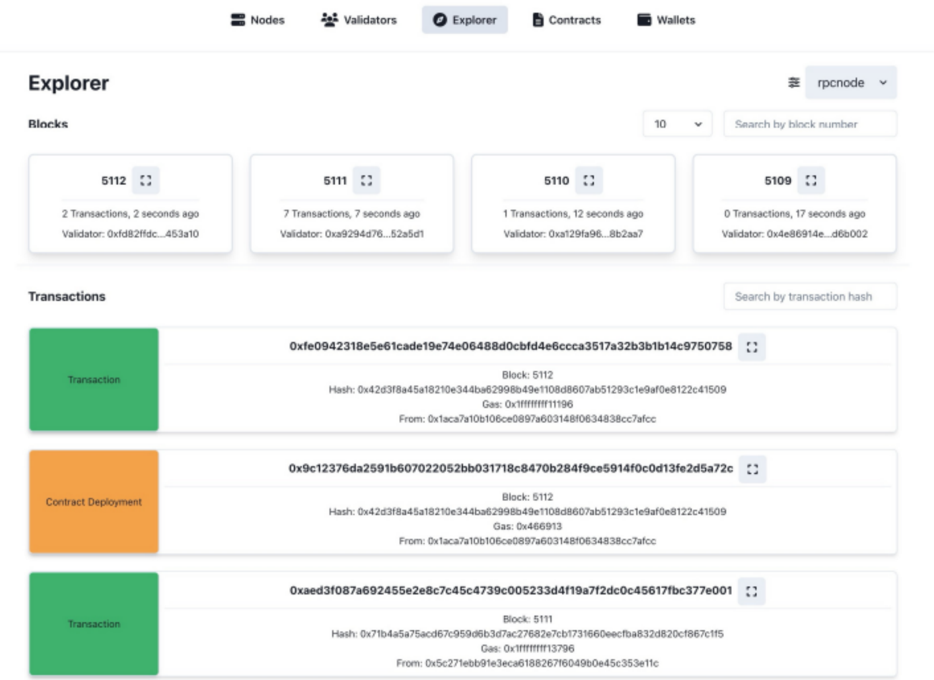


2) *Validators:* **The Validators** menu lists the active validators in the network and provides options to manage them. Administrators can view current validators, remove them if necessary, and propose new validators by entering their address. This interface is essential for managing the validators responsible for approving transactions and maintaining the network's consensus. When

proposing a new validator, approval from a majority of the nodes in the network is required. For instance, at least 51% of the total nodes must agree for the new validator to be accepted. This ensures that the network maintains decentralized decision-making and that only validators with consensus approval can participate in the consensus process.

3) *Explorer:* The **Explorer** menu allows users to explore the blockchain by viewing blocks and transactions processed by the network. It displays the latest blocks, their transaction count, and the validators responsible for those blocks. Additionally, users can search for specific transactions or blocks, providing transparency and traceability within the blockchain, as shown in Figure 5. Furthermore, any new transactions or activities processed by the network will appear in this section in real-time. This ensures that users can monitor the state of the blockchain and track recent activities. After a few seconds, the transaction records will disappear from the real-time feed, but they remain accessible through search or block exploration, preserving the integrity and transparency of the blockchain data.

Fig. 5. Blockchain Explorer for Blocks and Transactions



DISCUSSIONS

Blockchain technology has fundamentally transformed how transactions are recorded and verified, introducing unprecedented levels of security and transparency. By decentralizing data storage across a network of nodes, blockchain eliminates the need for a central authority, thereby creating a "trustless" environment where participants can confidently engage without relying on any single entity. The introduction of smart contracts on platforms like

Ethereum further enhances this capability by allowing developers to automate and streamline processes that traditionally required intermediary oversight, such as financial transactions and supply chain management. This shift not only increases operational efficiency but also reinforces accountability, as all actions are recorded immutably on the blockchain, ensuring that data integrity is maintained and easily verifiable by all authorized stakeholders.

In the context of higher education, the application of a decentralized system for tracking student achievements through a Student Activity Credit Unit (SACU) exemplifies the practical implementation of blockchain technology's benefits. By utilizing a secure and scalable architecture built on Hyperledger Besu, educational institutions can manage student records transparently while ensuring that achievements are validated in a tamper-proof manner. This innovative approach allows for the integration of both academic and non-academic activities, fostering holistic student development while also meeting institutional requirements. As a result, graduates are better equipped with the skills and experiences necessary for professional success, and universities can uphold transparency in their evaluation processes, ultimately contributing to improved trust and accountability in how achievements and qualifications are recognized.

CONCLUSION

The design of a decentralized Student Activity Credit Unit (SACU) recording system is aimed at creating a secure and efficient platform for tracking student achievements. By leveraging blockchain technology, particularly through the implementation of a private network using Hyperledger Besu, the system ensures that all activity records are immutable and transparent, which enhances trust among stakeholders such as students, academic staff, and verification bodies. Key components of the system include a user-friendly web interface for activity submission, the use of smart contracts for automating verification processes, and decentralized storage solutions to safeguard supporting documents. The architecture supports scalability and maintains data integrity, ultimately leading to significant improvements over existing systems in terms of transparency, security, and administrative efficiency, thereby facilitating better management of student accomplishments throughout their educational journeys.

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