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DEVELOPMENT OF A BLOCKCHAIN-BASED STUDENT EDUCATIONAL RECORD SYSTEM IN TERTIARY EDUCATION

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ABSTRACT

Blockchain technology has emerged as a transformative innovation, offering unparalleled advantages in security, transparency, and data integrity across various domains. In tertiary educational institutions, managing student records, course registrations, and academic data is often challenging due to data inconsistency, lack of transparency, and risks of unauthorized access. To address these issues, this study aimed to design and implement a Student Educational Record System (SERS) on the Solana blockchain network. A Prototyping Approach was adopted, utilizing the Solana blockchain and the Anchor Framework for smart contract development. The front-end was implemented using React.js, integrated with Phantom Wallet for secure authentication and blockchain interaction. Key functionalities including account creation, role assignment, course management, and grade handling were developed incrementally to enhance usability. The system was evaluated on Solana Playground and compared with centralized academic record system using throughput, deployment cost and scalability. The results of the evaluation and comparison indicated that the system's throughput test demonstrated that SERS achieved an average TPS of 23.8, indicating a high-speed transaction processing capability compared to traditional centralized academic record. The tests showed that as transaction volume increased, response times remained relatively low, demonstrating system's high scalability. Additionally, deployment cost analysis showed that SERS offers a cost-effective alternative, reducing transaction expenses compared to other blockchain-based solutions. These findings reveal that the developed blockchain-based student educational record system addresses critical challenges in academic data management. By leveraging Solana's security, scalability, and low-cost transactions, the system provides a reliable, transparent, and economically viable platform for academic institutions. This work underscores the potential of blockchain technology to revolutionize educational record management, offering a model for future research and real-world implementations in the education sector.

Keywords: Blockchain, Educational Records, DApp, Solana, Throughput, Scalability

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1. INTRODUCTION

The advent of blockchain technology has brought about significant transformations in various sectors, including finance, healthcare, supply chain management, banking, Internet of Things (IoT) etc. However, its application in the education sector has gained significant attention in recent years due to its potential to enhance the security and integrity of educational records and credentials [3];[10]. In higher institution of learning, the need for a secure and reliable system for managing educational records and credentials has been a long-standing issue. The country's education system has faced several challenges such as certificate forgery, result falsification and loss of records due to administrative errors or system failures [6].

The management of student educational records in tertiary education has become increasingly complex due to technological advancements, rise in demand for transparency and the need for enhanced data security. However, conventional record-keeping systems often paper-based or reliant on centralized databases are vulnerable to risks such as unauthorized access, data breaches, opacity, system downtimes, and document forgery. Academic records contain a wealth of personal and confidential information about students, including grades, transcripts, and certificates, all of which are increasingly targeted by cyber-attacks [15]. With the growing frequency and sophistication of cyber-attacks, including data breaches and identity theft, ensuring that student data is stored securely has become a critical issue. According to [15], over 15 million student records were compromised in data breaches in the United States alone from 2015 to 2020, highlighting the vulnerability of centralized systems. These breaches not only compromise the privacy of students but also erode the credibility of the academic institutions that issue the records. Consequently, adopting a secure, transparent, and tamper-proof solution is crucial to safeguarding student records from these threats.

Blockchain technology therefore, presents a paradigm shift in how educational records can be managed in a decentralized, immutable and transparent manner. The decentralized nature of blockchain allows records to be stored across multiple nodes. This will allow easy accessibility and eliminate the single point of failure or the existence of a super administrator who can retrieve data of general administrative framework, learning and research associated with centralized systems. The immutability of blockchain ensures that once a transaction is created, it cannot be altered or deleted, thus maintaining its integrity and authenticity over time [5] and its transparency also allows for easy verification of records by authorized parties, further enhancing trust in the system.

The implementation of blockchain technology in the Nigerian universities could address several critical issues. First, it would significantly reduce the incidence of academic fraud by making it virtually impossible to alter or forge educational records. This would enhance the credibility of Nigerian qualifications both locally and internationally. Second, it would streamline the administrative processes involved in managing educational records, reducing the workload on administrative staff, minimizing the risk of errors as well as ensuring faster and more accurate record updates [1]; [4]. Moreover, the transparency and immutability of blockchain can foster greater trust between educational institutions and stakeholders such as employers, accreditation bodies, and students.

Employers, for example, can easily verify the authenticity of a candidate's academic credentials without relying on intermediaries, thus speeding up the recruitment process and ensuring that only qualified individuals are hired [14]. Accreditation bodies can also benefit from real-time access to verifiable records, facilitating the accreditation process and ensuring compliance with educational standards.

2. REVIEW OF RELATED WORKS

This section discusses some of reviewed related works: [11] proposed a Blockchain-based model for securing academic transcript records in Higher Education. The study aimed to address issues of tampering, forgery, and centralization of academic records. The authors presented a decentralized model utilizing Blockchain Technology to store and manage academic transcript records, ensuring immutability, transparency, and security. However, the model is a theoretical framework and lack practical implementation. [9] explored the application of blockchain technology in securing student records, highlighting its potential in ensuring data integrity, transparency, and security. The authors design a blockchain-based system using Ethereum, demonstrating its effectiveness in a real-world educational institution.

[12] proposed a blockchain-based models for student information systems. The study aimed to avoid the role of a super administrator or a centralized exposed store where data integrity is vulnerable. The authors proposed three models for pushing towards electronic community where genuine certificates can be issued and published to the interested parties without the need for involving a centralized administrator. However, the proposed models lack practical implementation. [7] proposed a blockchain-based secure student data management system to address concerns related to data security, integrity and transparency in educational institutions. The authors design and implement a system using Ethereum blockchain, smart contracts and solidity programming language demonstrating its effectiveness in securing student records. But the system is flawed with limited testing scope with no evaluation of performance metrics.

[13] proposed a blockchain-based framework that uses the decentralized and immutable nature of blockchain to secure students' records. The framework aims to improve transparency, accountability, and security in handling educational records. It ensures that student information is stored in a tamper-proof manner, minimizing the risk of unauthorized access or alterations. The study highlights the importance of decentralization in education data management. However, the limitations in their proposed framework include scalability issues that may arise with large volumes of records and limited practical validation in that the proposed framework is theoretical, with limited real-world testing.

[2] explores the use of blockchain technology for securing educational data and credentials. It emphasizes the decentralized and immutable features of blockchain, which can be used to verify the authenticity of academic records and protect sensitive student information from fraud or unauthorized access. The research highlights the potential of blockchain technology to enhance the security, transparency, and efficiency of educational systems. The study demonstrates how blockchain can be used to securely store educational credentials, making it nearly impossible to alter or forge academic records.

The paper suggests that using blockchain can help eliminate issues related to lost or falsified credentials, enabling employers and academic institutions to verify qualifications easily. Moreover, the decentralized nature of blockchain reduces the reliance on central authorities, which can be vulnerable to breaches.

2. METHODOLOGY

Solana, Rust, Anchor framework, React.js, phantom wallet and chainstack were used to develop the blockchain-based student educational records system. These technologies were employed to ensure data security, integrity and transparency. Solana exceptional throughput, high scalability and cost-effective transactions make it a suitable blockchain technology for this research. React.js was used to build user interface for students, lecturers and administrators. This framework is chosen for its flexibility, scalability and ability to create responsive and dynamic user interfaces. Phantom wallet was used to facilitate secure communication between the client-side interface and the Solana blockchain. Phantom serves as the user's wallet and holds private keys to authorize and sign transactions securely. Students, lecturers, and admins will use Phantom to authenticate transactions such as registering for courses, uploading grades, or modifying student records. Chainstack acts as an intermediary service that ensures the reliability and performance of transactions sent to the blockchain network. It relays requests from the Phantom wallet to the Solana blockchain and processes responses accordingly. Smart Contracts were developed using Rust Anchor Framework and deployed using the Solana CLI and Cargo tools. These ensure efficient contract execution and deployment on the Solana blockchain. These contracts enforce business logic, ensuring that only authorized users (students, lecturers, and admins) can perform actions like creating courses, registering students, or uploading grades. The contracts also ensure that data is immutable and securely stored. The system as shown in Figure 1 involves three distinct account types Admin, Lecturer, and Student each with specific roles and privileges within the system.

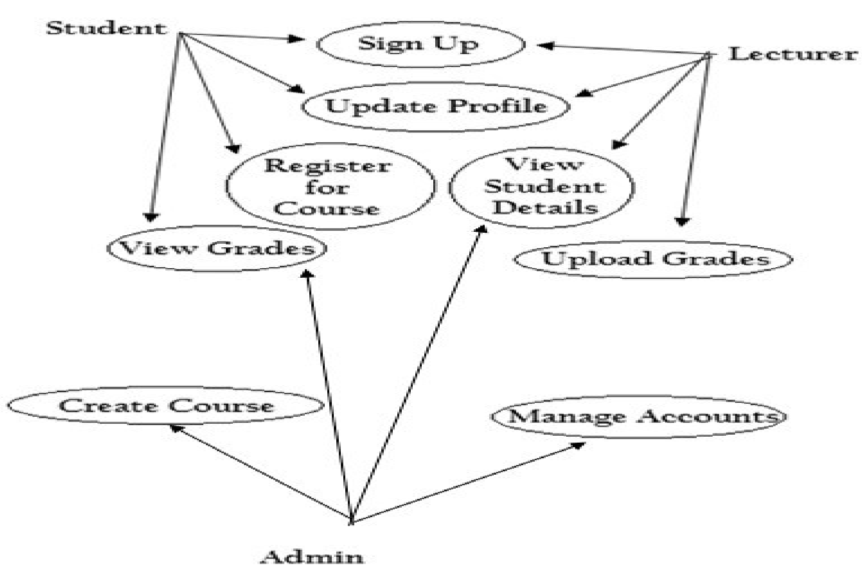

Figure 1: Design for the Blockchain-Based Student Educational Record System

The functional components of the system and user roles are as follows:

Admin

i. Authenticate Account Creation for students and lecturer as described in Algorithm 1, Table 1 outlines the process of authenticating a user account ensuring no duplicate accounts. The Admin either approves or rejects the request. Upon approval, the account details are activated and stored immutably on the Solana blockchain. The smart contract then generates a confirmation token, which is returned to the user, confirming account activation. If rejected, a rejection notice is returned.
ii. Create Courses: Admin creates and manages course offerings.
iii. View Student Details: The admin can view all the students' details but can't modify them.
iv. View Grades: Admin can keep track and view the uploaded grades by the lecturers but won't be able to tamper with it.

Lecturer

Lecturers are responsible for managing course-related tasks, such as uploading student grades, selecting courses assigned to them and updating their personal and academic information.

i. Upload Grades: As depicted in Algorithm 2, Table 2, and the lecturer logs in and selects the course they are to take via the React.js front-end. The lecturer will then input grades for the students registered in that course. The smart contract will then verify the lecturer's authority to upload grades for the selected course (based on their assignment). The system will encrypt the student grades and stores them immutably on the blockchain. The system then sends a grade notification token to the respective students, confirming that their grades are available for viewing. The smart contract then confirms that the grades have been uploaded and stored on the blockchain, and a notification is issued to the students.
ii. Input and Update Personal and Academic Information: Lecturers can manage and update their own personal and professional information (e.g., degrees, courses taught) on the system.
iii. Self-Assign Courses: Lecturers can pick the course they are to take after it has created by the admin. After these courses are selected they would be included in the Assigned Course interface.

Student

Algorithm 3 outlines the process by which a student can register for courses created by the admin, view their grades, and manage their personal and academic information.

i. Course Registration: The student would log into the system and selects a course from the list of available courses created by the admin. The smart contract will then check if the student meets the eligibility criteria (e.g., prerequisites). Upon successful verification, the student will then be registered for the course. The registration is stored on the blockchain, ensuring immutability. The system will issue a registration confirmation token to the student as proof of enrollment. The student will finally receive confirmation of their course registration as shown in Algorithm 3, Table 3.
ii. View Grades: Students can securely access their grades once uploaded by the lecturer. The grades are retrieved from the blockchain using the student's digital identity.
iii. Input and Update Personal and Academic Information: Students can update their personal information (e.g., contact details) and view academic information stored on the blockchain.

Table 1: Admin Account Authentication

Algorithm 1: Admin Account Authentication

Input: User details
Output: Confirmation token
1. Admin receives a request for a new account (student or lecturer).
2. The Anchor smart contract validates the request and stores it temporarily in a pending state.
3. Admin reviews the request and either approves or rejects it.
4. Upon approval, the smart contract activates the account and stores the details on the blockchain, while on rejection the user is redirected back the index page and provided with a "failed to create account" alert.
5. A confirmation token is sent to the account holder.

Table 2: Lecturer Grade Upload

Algorithm 2: Lecturer Grade Upload

Input: Student grades
Output: Confirmation of grade upload
1. The lecturer logs in and selects the course for which they are to take.
2. The lecturer inputs grades for students registered in the course.
3. The smart contract verifies the lecturer's authorization for the course.
4. The grades are encrypted and stored on the blockchain, tied to the respective student's digital identity.
5. A grade notification is sent to the students.

Student Course Registration

Algorithm 3: Student Course Registration

Input: course ID
Output: Confirmation of successful course reg
1. Student logs into the system and selects a course from the available courses created by the admin.
2. The Anchor smart contract verifies if the student is eligible for the course (e.g., prerequisite courses completed).
3. The student is registered for the course, and the registration details are stored on the blockchain.
4. A course registration token is issued to the student for future reference.

4.RESULTS AND DISCUSSION

4.1 Graphical Interface for the Developed System

The Student Educational Record System (SERS) was designed as a blockchain-based decentralized application (DApp) deployed on the Solana blockchain. By leveraging blockchain's key features immutability, transparency, and decentralized security the system ensures integrity and reliability in managing educational records. The user interface (UI) prioritizes accessibility, ease of use, and role-based customization, enabling students, lecturers, and administrators to interact seamlessly with the platform. The UI design prioritizes efficiency and security, ensuring that users can interact seamlessly with the system. By integrating blockchain authentication and role-based access control, the platform eliminates common vulnerabilities found in traditional educational record systems. Furthermore, real-time transaction feedback enhances user confidence and system credibility.

4.1.1 Connect Wallet Page

The Connect Wallet Page, shown in Figure 2, serves as the gateway to the SERS platform. Users must connect their Phantom wallet to proceed. This page not only ensures the security of user authentication but also validates their identity using their wallet's public key. The integration of blockchain wallet authentication guarantees that only authorized users gain access to the platform, mitigating risks such as unauthorized account usage or data tampering.

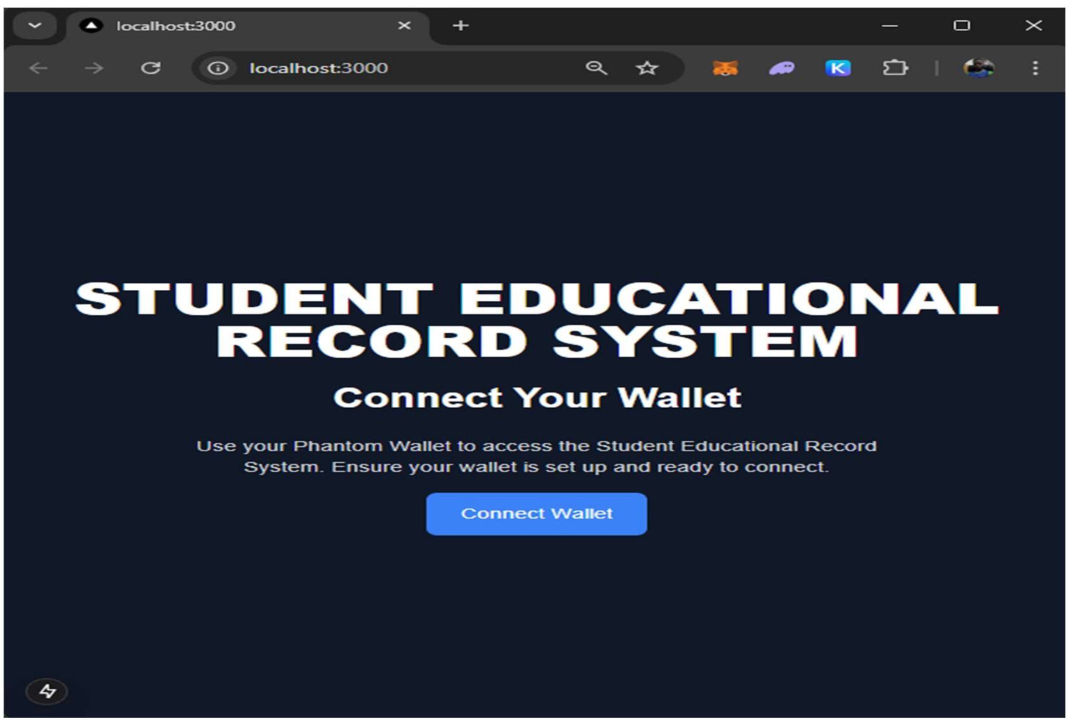

Figure 2: Connect Wallet Page

4.1.2 Role Selection Page

Upon successful wallet authentication, users are redirected to the Role Selection Page (Figure 3). This page dynamically determines user roles based on their wallet's public key. Admin users are automatically redirected to the Admin Dashboard, while lecturers and students are prompted to select their role. Users not yet registered are presented with a request form to join the desired role, further enhancing role-based access control.

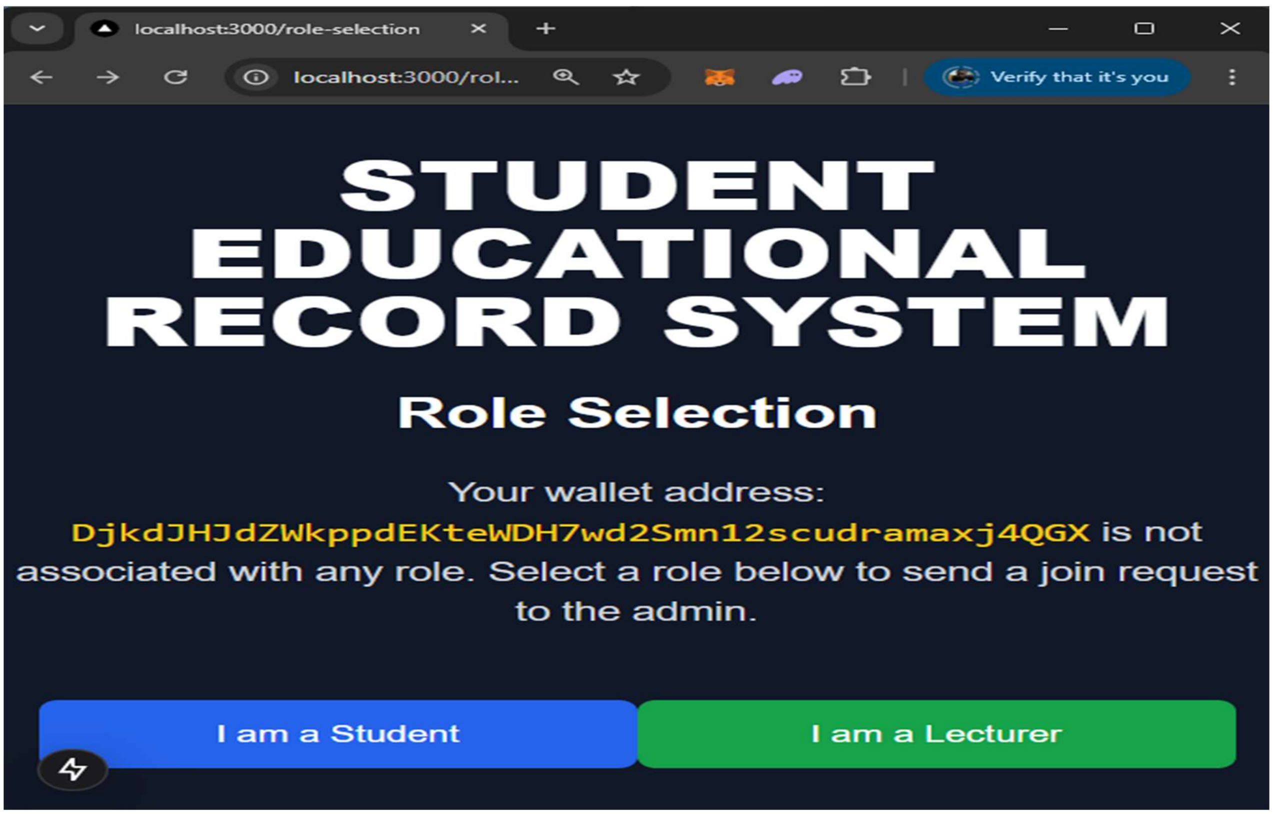

Figure 3: Role Selection Page

4.1.3 Admin Dashboard

The Admin Dashboard, depicted in Figure 4, offers administrators a comprehensive set of tools to manage the system's core functionalities. Admins can approve or reject account requests, create new courses, and view detailed lists of registered students and their grades. The dashboard's intuitive design ensures efficient navigation between functionalities while providing real-time blockchain feedback on executed actions.

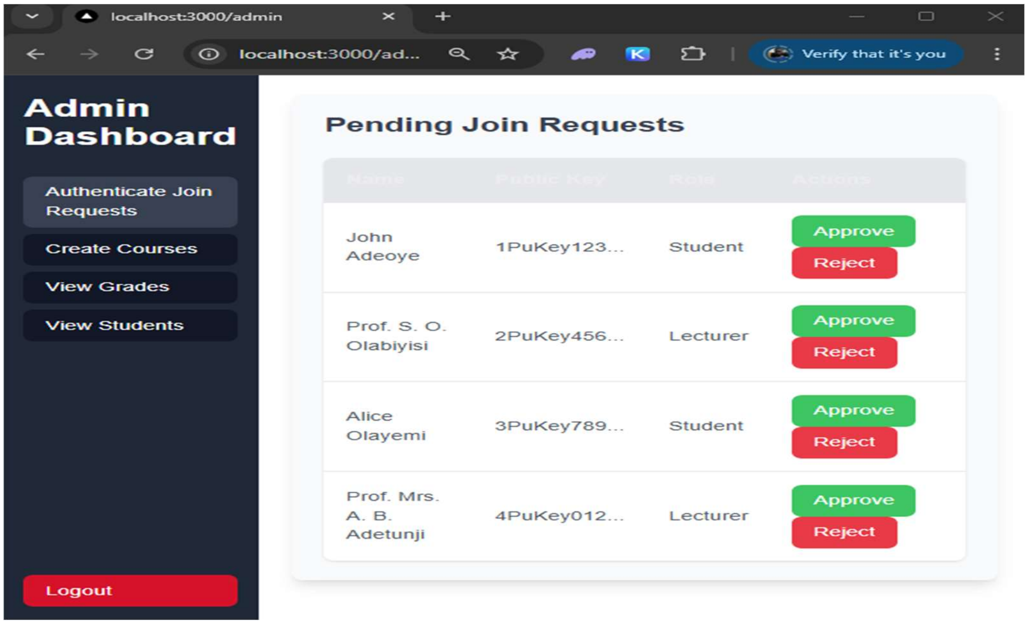

Figure 4: Admin Dashboard

4.1.4 Lecturer Dashboard

The Lecturer Dashboard (Figure 5) equips lecturers with essential tools for academic management. Lecturers can view assigned courses, upload grades, and access student lists. Blockchain integration ensures that all recorded data remains immutable, preventing grade tampering and enhancing trust in academic records.

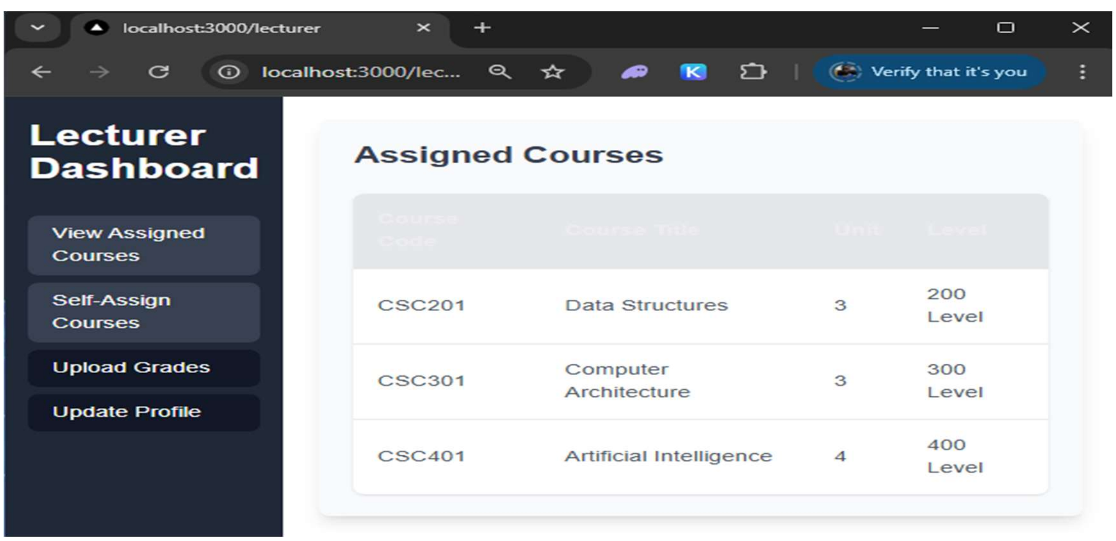

Figure 5: Lecturer Dashboard

4.1.5 Student Dashboard

The Student Dashboard (Figure 6) allows students to view their academic records, including registered courses and grades. Transactions such as course registration and grade updates receive immediate blockchain confirmation, ensuring real-time transparency. This fosters trust between students and academic institutions while eliminating inefficiencies in record retrieval.

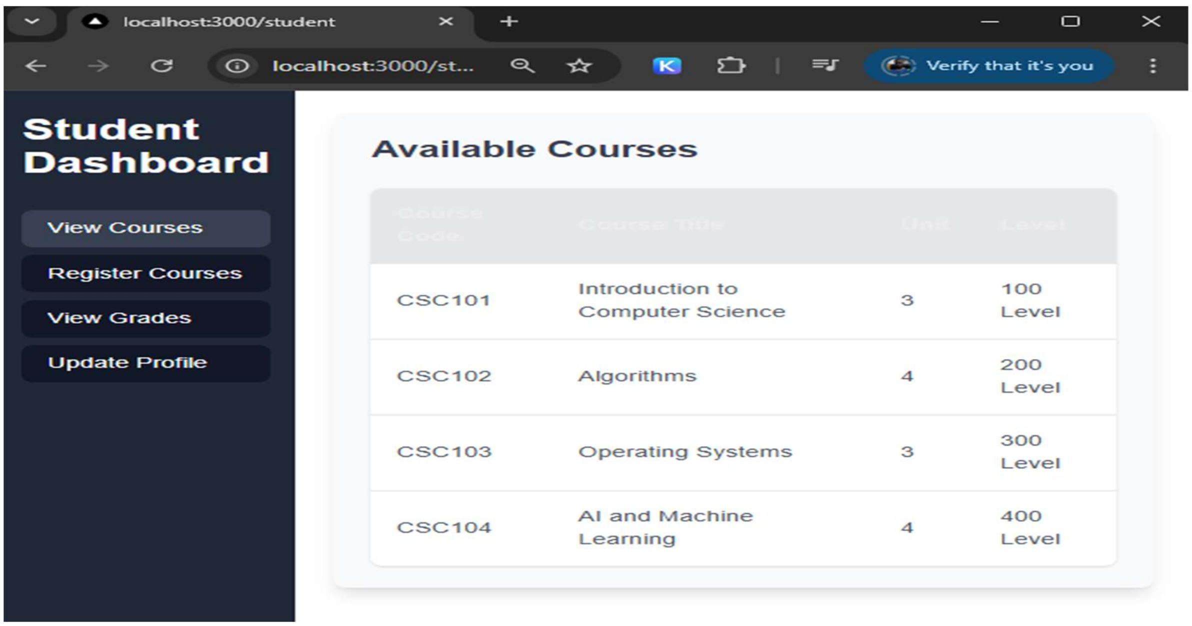

Figure 6: Student Dashboard

4.2 Throughput Analysis

Throughput, measured in transactions per second (TPS), is a key performance metric that determines the efficiency of blockchain-based applications. For SERS, throughput indicates how quickly student records, course registrations, and grade uploads are processed within the system.To evaluate throughput, smart contracts were deployed and tested using the Solana Playground. The testing procedure involved executing multiple transactions, including course registrations and grade uploads, in batches. The time taken for these transactions to be confirmed on the blockchain was recorded, and throughput was calculated using equation 1:

$$Throughput = \frac{\text{Total Transactions}}{Time\ Taken\ (Seconds)} \quad (1)$$

Block time, which represents the time taken to confirm a particular function, was also recorded for each transaction type. Multiple test runs were performed to ensure accuracy, and results were averaged to obtain a reliable TPS value.

The throughput tests demonstrated that SERS achieved an average TPS of 23.8, indicating a high-speed transaction processing capability compared to traditional centralized academic record systems. Table 4 provides an overview of block times, transaction counts, and computed throughput values. A comparative bar chart (Figure 7) illustrates the throughput performance of SERS against other systems, including centralized databases and alternative blockchain platforms like Ethereum. The high throughput of SERS ensures that student records and academic transactions are processed in near real-time, enhancing efficiency and usability. This performance advantage makes blockchain-based student record systems a viable alternative to traditional solutions, particularly for institutions handling large volumes of academic data.

Table 4: Block Time and Throughput for Different Functions

Function	Block Time (Seconds)	Total Transactions	Throughput (TPS)
Approve/Reject Request	21	500	23.81
Create Course	24	600	25.00
Fetch Requests	29	700	24.14
Fetch Courses	41	800	19.51
Fetch Profiles	32	750	23.44
Fetch Registered Courses	29	650	22.41
Register Course	27	720	26.67
Update Profile	39	680	17.44
Upload Grade	26	780	30.00
View Grade	30	740	24.67

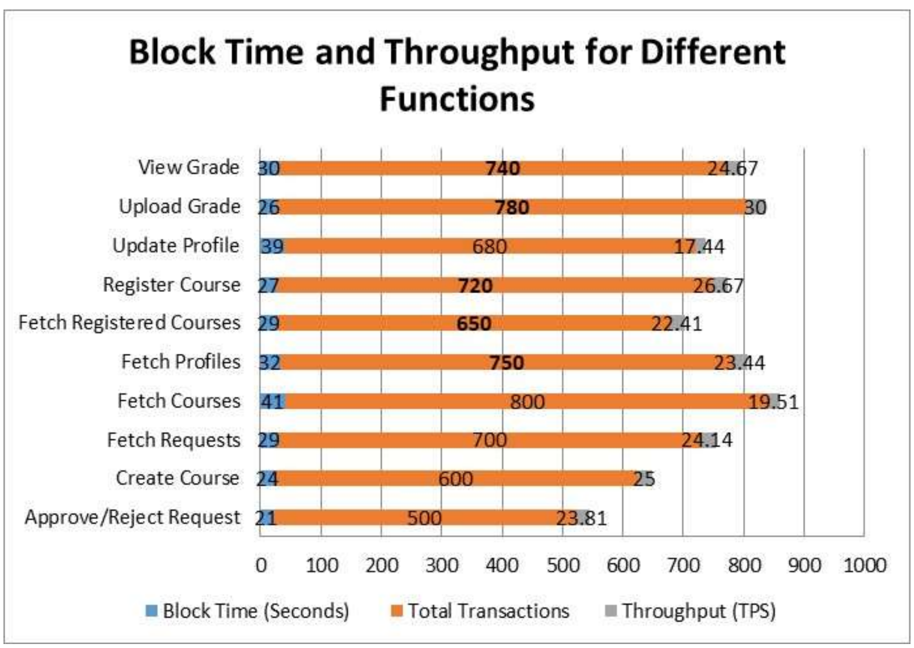

Figure 7: Comparative Throughput Performance of SERS vs. Other Systems

4.3 Deployment Cost

Deployment cost in blockchain refers to the fee required to put a smart contract or application on a blockchain network. It varies depending on the complexity of the contract and the chosen blockchain platform. Deployment cost involves additional transaction fees (like "gas" on Ethereum) that can range from a few dollars to several hundred dollars for a basic deployment. This makes deployment cost in blockchain network such as Ethereum more costly than Solana. Deployment costs are a critical metric in evaluating blockchain-based applications, as they directly impact the feasibility and scalability of the system. The SERS platform was deployed on the Solana blockchain using the Anchor Framework, a development tool that optimizes both transaction execution and smart contract deployment. Solana's Proof of History (PoH) consensus mechanism further minimizes costs by reducing computational overhead.

The deployment costs of SERS were analyzed for each smart contract function, as summarized in Table 5 Functions such as approve_request and fetch_profile incurred higher costs due to the complexity of their operations and the size of the associated data structures. By contrast, simpler functions like fetch_requests and register_course required minimal computational resources, leading to significantly lower costs. For instance, the approve_request function cost 2.85340044 SOL, reflecting the computational effort required to manage role assignments and ensure data integrity and also functions like fetch_profile cost 0.42716528 SOL, showcasing the efficiency of blockchain data retrieval for profile management. The low deployment costs of Solana demonstrate its economic viability compared to traditional systems, such as Ethereum, which incurs significantly higher gas fees due to its proof-of-work mechanism. The cost efficiency of Solana makes SERS an attractive solution for large-scale academic systems, where frequent transactions are required.

Table 5:Deployment Costs for SERS Functions

Function	Deployment Cost (SOL)
Approve/Reject Request	2.85340044
Create Course	0.003933
Fetch Requests	0.001087
Fetch Courses	0.00229
Fetch Profiles	0.42716528
Fetch Registered Courses	0.001565
Register Course	0.0015
Update Profile	0.002005
Upload Grade	0.00166
View Grade	0.00169

4.4 Scalability Analysis

Scalability refers to a system's ability to handle an increasing number of transactions without significant performance degradation. For blockchain-based educational record systems, scalability ensures that growing student populations and transaction loads do not slow down system operations. Scalability was assessed by simulating increasing transaction loads in the Solana Playground.

The system was tested under different loads, ranging from 100 to 1,000 concurrent transactions, to observe its response time and resource efficiency. The tests showed that as transaction volume increased, response times remained relatively low, demonstrating Solana's high scalability. The results are summarized in Table 6 and a line chart (Figure 8) illustrates response times under different transaction loads. The results indicate that SERS can efficiently handle growing transaction volumes, making it a scalable solution for large academic institutions. Its ability to maintain low response times under high loads suggests suitability for real-world deployment.

Table 6: Scalability Test Results

Number of Transactions	Average Response Time (Seconds)
100	1.2
250	2.3
500	4.5
750	6.8
1000	9.2

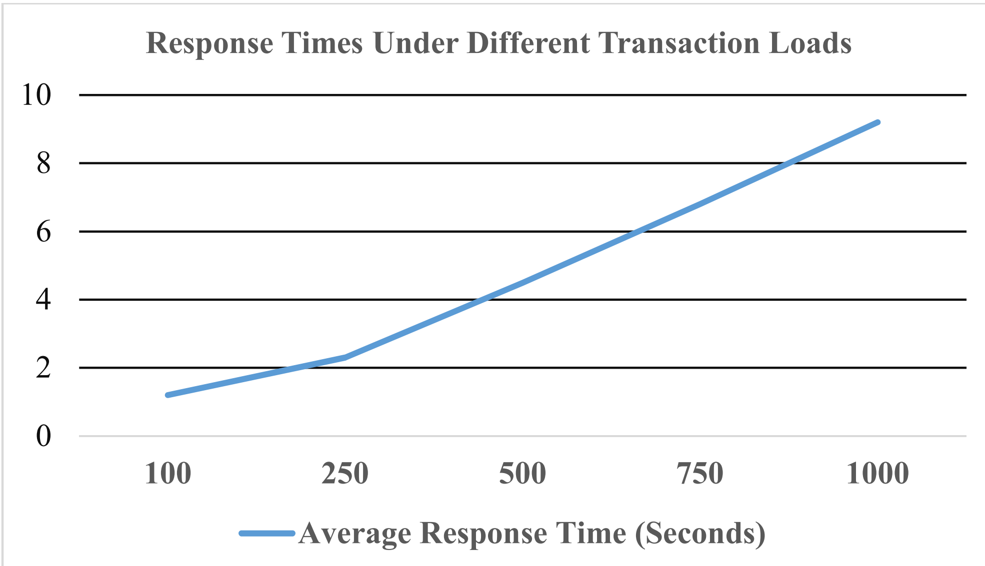

Figure 8: Response Times under Different Transaction Loads

4.5 System Validation

While comparing SERS with an actual centralized academic system is crucial for validating its performance, the lack of publicly available performance metrics for centralized systems makes direct comparisons challenging. Given these limitations, we emphasize the inherent advantages of SERS over traditional systems based on well-documented characteristics of blockchain and centralized architectures. The validation results depicted in Table 7 indicate that SERS provides a more secure, transparent, and scalable solution for managing student records compared to traditional centralized systems. The inherent strengths of blockchain technology, such as immutability and decentralization, address key challenges found in conventional academic management platforms.

Table 7: Comparison of SERS with Centralized Systems

Criteria	SERS (Blockchain)	Centralized System
Security	High (Immutable, tamper-proof)	Medium (Prone to data breaches)
Transparency	High (Decentralized, publicly verifiable)	Low (Limited access and auditing)
Data Integrity	High (Cannot be altered after confirmation)	Medium (Can be modified by administrators)
Transaction Speed	High (23.8 TPS on Solana)	Medium (Dependent on server performance)
Scalability	High (Distributed ledger, scalable nodes)	Low (Limited by server capacity)
Cost-Effectiveness	Low Deployment Cost	High Maintenance Cost

5.CONCLUSION AND RECOMMENDATION

5.1.Conclusion
In conclusion, this work successfully designed and implemented a blockchain-based Student Educational Record System (SERS) on the Solana blockchain using the Anchor Framework. The system integrates decentralized data storage, secure role-based access, and dynamic management functionalities for academic operations such as course creation, registration, and grade management. By leveraging the Solana blockchain, SERS ensures high levels of transparency, security, and efficiency in managing academic records.

5.2.Recommendations
Future research could be done by implementing the system in a live environment within a tertiary institution is essential to test its effectiveness under real-world conditions. This deployment will facilitate the assessment of the system's scalability, performance, and user satisfaction, providing valuable insights into its practical applicability and reliability. Gathering feedback from key stakeholders, including administrators, lecturers, and students will help identify areas of improvement in the user interface, functionality, and system responsiveness.

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