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Review

Efficient and Secure Record-Keeping: A Review of Smart Contract-Based Student Marks Management Systems in Universities

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Abstract: Blockchain stores the transaction sequentially in the form of linked blocks. The decentralized and distributed nature of the blockchain makes data easily accessible to the participants of the blockchain network. There are many applications of blockchain in the IT industry as it is one of the growing technology. Traditional education system suffers from marinating the data centrally. Centralized data are a threat to data loss as well as attack. Using blockchain to store and manage data will help to make the data secure, transparent, and available to the different users of the education system. In this study, we have proposed the blockchain based marks management system for the universities. The proposed model implements the smart contract to track the student's academic progress. Different authorized and authenticated users can join the private blockchain network. Nodes in the network have different privileges, which are implemented in the smart contract. Faculty and students are the two main nodes of the network. Faculty can add the students' marks, and students can view and track the progress of the respective subjects. The model also compared the error frequencies between a manual system and a blockchain-based system across five error types: Transposition error, transcription error, calculation error, omission error, and formatting error. The blockchain-based system was particularly effective in reducing omission errors, with an 86.67% reduction compared to the manual System. The blockchain-based system also achieved a 100% reduction in Formatting Errors, showcasing its ability to maintain data integrity and consistency. The immutability feature of blockchain will provide the data integrity of the marks of the student. Overall, the blockchain-based system outperformed the manual System across all error types, demonstrating significant improvements in data accuracy and reliability.

Keywords: Block Chain, Smart Contract, Consensus Mechanism, Distributed Ledger, Traditional Marks Management System

Introduction

A blockchain opens up new possibilities for maintaining data integrity by employing decentralized data repositories (Nguyen *et al*., 2020). The automated management systems of individual higher education institutions or groupings of educational institutions can be upgraded to use blockchain technology (Nguyen *et al*., 2020). Because of its fundamental property, blockchain can record, store, and update data without relying on a single central node (Sabila and Rahardjo, 2019). The Fig. (1) depicts the working of blockchain technology. In order to encourage educational businesses and IT companies to offer online education services, create digital educational resources, and investigate novel models of online education services, the State Council released a number of "Internet +"-related measures in 2015 (Hang, 2017; State Council, 2016). The

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blockchain is just beginning to be implemented in education. Educational institutes are smaller in numbers than those who are using blockchain for one or another purpose. The blockchain technology, also known as distributed ledger technology or ledger system (State Council, 2016), employs a distributed storage consensus technique and a decentralized architecture to store transaction data securely. In addition, the education domain faces challenges like Democratizing and automating HEIs, reducing costly university bureaucracy, and Lagging behind in technology adoption (Haugsbakken and Langseth, 2019). Several institutions employ the consortium blockchain, which is multi-centralized and semi-public. In a traditional marks management system, data is typically stored in centralized databases, making it vulnerable to unauthorized access, data loss, and manipulation. In contrast, a blockchain-based marks management system utilizes decentralized ledgers, ensuring greater security, transparency, and immutability of records, which significantly reduces the risk of fraud and enhances trust among stakeholders. This innovative approach also facilitates real-time updates and verifications, streamlining the overall management process. To enhance the security of the student's marks, institutes follow the procedure of assigning the ID numbers, affixing the photo of the student, and adding the other details of the student like, parent name, birthdate, birthplace, and registration number on the marks sheet. In order to provide security to the students' confidential data, blockchain technology can be used because of its tempered-proof nature. In this study, we have developed a smart contract for implementing the different functionalities and operations required to manage the students' grades.

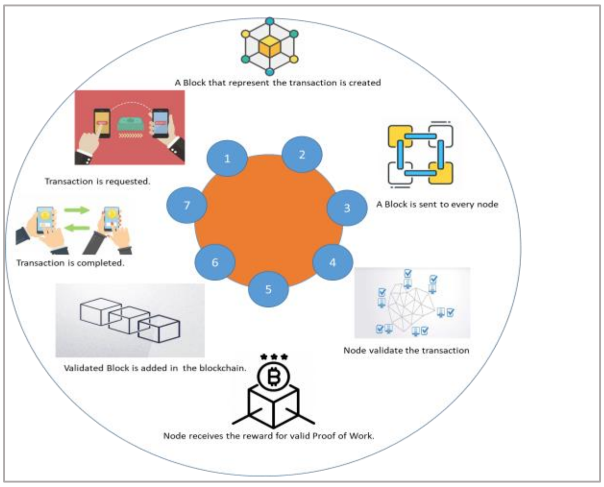

Fig. 1: Working of Blockchain

Applications of Block Chain Technology

In this Section, most of the fields in which blockchain could be useful are covered. Though blockchain is a trending technology in the field of IT, it can be applicable to financial sectors as well as the business sectors. Efforts have been made to concentrate on the need for blockchain technology in many fields by taking examples from various industries. The following are some areas where a blockchain could be the better solution.

Supply Chain and Provenance

Figure (2) represents the scenario of supply chain management. Here, supplier B is buying ice cream from supplier A; supplier B transports ice –cream to C, which is made by supplier A. Upon delivery of the ice- cream, supplier C found that it had already melt. In this case, who is responsible, B or A? Supplier B says that A's storage was not proper, and at the same time, a says that Supplier B kept it in the transporting vehicle too long. One of the solutions to this problem is putting the sensors in B's storage and truck and A's storage and truck. However, it is possible that someone would change the data of the sensors. Another solution to this problem is blockchain technology. As blockchain is tempered proof, no one can change the data, and data integrity is maintained. In addition, blockchain is a distributed, decentralized, and public ledger. No one can disagree on the data.

Bank Fraud

If someone became a victim of fraud, in this case, how to convince the bank is a major question. Following may be the cases of fraud where there is no way to prove the side of the victim. A cheque was used to pay someone, but you never wrote it, i.e., someone forged the signature. The amount of the cheque is modified. e.g., An extra zero is put. Someone gets the password and redirects the OTP to some other SIM card. In these cases, how do we argue with the bank that the signature was forged or the amount was modified, as we do not have any proof of this? The way transactions are maintained by the bank is not so transparent. However, we trust the banks, as they are trusted third parties. Blockchain is one of the solutions which will provide transparency and maintain the integrity of the data. Without a trusted third party, trustworthiness can be enforced.

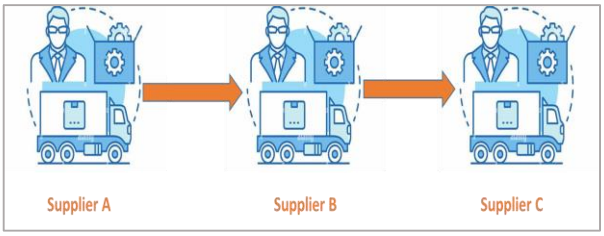

Fig. 2: Scenario of supply chain management

Land Record

If someone became a victim of fraud, in this case, how to convince the bank is a major question. Following may be the cases of fraud where there is no way to prove the side of the victim. A cheque was used to pay someone, but you never wrote it, i.e., someone forged the signature. The amount of the cheque is modified. e.g., an extra zero is put. Someone gets the password and redirects the OTP to some other SIM card. In these cases, how do we argue with the bank that the signature was forged or the amount was modified, as we do not have any proof of this? The way transactions are maintained by the bank is not so transparent. However, we trust the banks, as they are trusted third parties. Blockchain is one of the solutions which will provide transparency and maintain the integrity of the data. Without a trusted third party, trustworthiness can be enforced.

Student Online Grade Submission and Management System

Student grades data is one of the confidential and sensitive data, and it is very important to provide integrity to the data. If some malicious party may change the grades there is no way to prove that data integrity has been violated. The malicious party may delete the history of logs of access to the database. Therefore, the System must be transparent enough to be trusted by professors and students as well. These are the problems where blockchain might come in handy as a technology to solve the complications.

Related Work

Since Nakamoto first proposed the blockchain idea for Bitcoin in 2008, it has received a lot of attention: An electronic cash system that is peer-to-peer (Since Nakamoto, 2008). Numerous studies have been conducted to comprehensively examine and present the corpus of contemporary research literature that has looked into the use of blockchain technology in educational settings either quantitatively or subjectively (Bhaskar *et al*., 2021; Haugsbakken and Langseth, 2019; Alkhajeh 2020; Application, 2020). The use of blockchain technology has the potential to benefit blockchain in many ways. Some of the advantages are low costs, improved safety, student enhancement, improved data access management, promoting accountability and integrity, boosting trust, supporting learners, identity authentication, improving the efficacy of student records and career decisions, and enhancing communication between the parties (Malibari, 2020). In this study, we have contributed to students' marks management system used in the university. The smart contract developed for the same can be used to avoid the involvement of the third party. It is also useful in keeping track of the student's grade history. Smart contracts, which are systems that autonomously move digital assets in accordance with arbitrary pre-specified rules, are another crucial field of investigation (Buterin, 2014). A blockchain can be categorized into many network types. Based on the types of applications, it supports and depicts how open the chain is (Nguyen *et al*., 2020). The ability of users to read or write the ledger is referred to as a network type in this context. A blockchain network is considered a permissionless blockchain if anyone can join it. For the applications like education institutions, permissioned blockchain is used. The rest of the Section represents the related work of using blockchain in the education field. In Nguyen *et al.* (2020), it is recommended that the input-write-validate-seal architecture is useful for VECefblock in order to strengthen the openness and trustworthiness of conventional educational management systems in schools and universities (Nguyen *et al*., 2020). The authors (Ali *et al*., 2022) have proposed three different types of models based on the size of the organization. The prototype model SIS (Student Information System) for storing, sharing aut,hentication, verification, and transparency of marks has been developed (Ali *et al*., 2022; Han *et al*., 2018). A platform for blockchain-based higher education credits called EduCTX has been suggested (Turkanovic *et al*., 2018). The EduCTX program seeks to streamline administrative procedures associated with the global higher education system; it does not seek to radically alter and reform the credit and grading systems currently in place in various nations but rather to make them more transparent and automated (Turkanovic *et al*., 2018). The research work by Kulkarnia *et al.* (2021) proposed decentralized documentation verification and assignment submission with the plagiarism checker (Kulkarnia *et al*., 2021). The System's verification and confirmation of authentic LORs and Research internships provided by the campus is another noteworthy feature (Kulkarnia *et al*., 2021). The System also seeks to serve as a decentralized, uncheckable interface for submitting assignments (Kulkarnia *et al*., 2021). The research work (Jain *et al*., 2021; Acharya and Binu, 2018) proposed a decentralized application (Jain *et al*.; Acharya and Binu) that employs smart contact for online testing in order to protect the privacy and security of user information management resources and make decisions for the educational System (Jain *et al*., 2021; Acharya and Binu, 2018). The authors (Samanta *et al*., 2021) have compared the computational cost of traditional examination systems with smart contract-based online exams. The smart contract, using Hyperledger composer, can be used to prepare mark sheets, course certificates, provisional degree certificates, and the verification demands of records (Samanta *et al*., 2021). The authors Mishra *et al*. (2020) also analyzed the performance in terms of cost and execution time using DApp in the educational domain for sharing students' credentials, experimented in Rinke by test network (Mishra *et al*., 2020). One more research for identity management using hyper ledger fabric in the educational field is carried out where the traditional technology is compared with blockchain-based technology for performance evaluation with optimal cost and time (Priya *et al*., 2020). Utilizing blockchain technology would ensure the authenticity, transparency, and validity of the data (Priya *et al*., 2020). The University of Indonesia has implemented a smart contract system and blockchain tokenization in universities in the payment transaction process (Gunawan *et al*., 2021). The Hashmani *et al*. (2020) have addressed the issue of the education systems adopting blockchain technology and how the Blockchain's features can be used for the Traceability and tracking of student performance (Hashmani *et al*., 2020). Mahamatov *et al*. (2020) also proposed a theoretical model to track the student's performance and thus keep track of all the activities (Mahamatov *et al*., 2020). A blockchain-based system for authenticating digital educational resources that carries out the fundamental tasks of resource information uploading, resource ownership, information verification, and resource owners' rights and interests’ protection is developed (Zhao *et al*., 2020). A user's profile can also be authenticated using blockchain technology. A smart contract using the truffle framework is developed to create and edit the user profile, which can be further extended using a blockchain for adding the courses, submission of students' grades, and merging all that to the registrar’s office (BouSaba and Anderson, 2019). Consensus mechanism is a key component of blockchain technology. The research work in Karande *et al*. (2020) represents the Proof-of-Authority-based decentralized System, which is used to store the results on an immutable blockchain such that each test result will be stored as a transaction (Karande *et al*., 2020). The authors (Aishwarya *et al*., 2020) propose dynamic face authentication using the Viola-Jones algorithm and SVM to check the integrity of the candidate at the beginning of the examination. After the test, the student is automatically evaluated by the System, and a legitimate score report and an E-certificate is produced (Aishwarya *et al*., 2020). Students' data are a very important and crucial part of any education system. Making the data secure and confidential is the biggest challenge. The research work by Myat and Soe (2020) proposed the CP- ABE-based model to make the university data available to the students and other stakeholders whose attribute values satisfy the access policy (Myat and Soe, 2020). In not only the universities but also the schools, Blockchain is used for the management of financial records. One of the research was carried out in Indonesia, in which authors proposed a database recording system operating on school funds using blockchain technology (Sabila and Rahardjo, 2019). Application of Blockchain varies in the education domain itself, from managing the financial record to the verification of certificates and transcripts to managing the online exam using Blockchain-based DApp. The authors present a method for connecting a platform with an expected interface to a blockchain network for storing data on students’ behavior (Valkanov and Petrov, 2019). This article (Valkanov and Petrov, 2019) detailed the architecture and key elements of a private network for keeping track of students' academic progress in the context of their online education. UniChain (Valkanov and Petrov, 2019) is a design of a blockchain-based System to manage the Electronic Academic Records in a secure, efficient, and interoperable manner. A new PoA-based incentive mechanism has been developed for governing the transaction and monitoring the computations performed on EAR (Daraghmi *et al*., 2019). Blockchain is about not only validating and verifying the data stored on it, but also the participating nodes can be the owner for accessing those data. The same concept can be applied in the domain of education, where the student becomes the owner of their academic data. The research by Juricic *et al*. (2019) depicts the blockchain based educational model, where students and employees both can have the access right to access and verify the data (Juricic *et al*., 2019). The Fig. (3) represents the Structure of Columbia-IBM Center for Blockchain and Data Transparency (n.d.) (Columbia-IBM and). This collaboration's goal is not just to create academic courses; rather, it is to assist the industries in developing data transparency and promoting trust (Columbia-IBM). One of the other applications of the blockchain in the education domain is online education. Schools and institutions around the world have made a startling switch from traditional instruction to online instruction because of the COVID-19 pandemic epidemic (Garg *et al*., 2022). One of the research is carried out in which authors have addressed the issues with online education, such as the inability to validate outcomes, loss of privacy, and faulty networking equipment (Singh and Sisodia, 2021). Blockchain is a rapidly developing computing technology that has found extensive use across a variety of industries thanks to its transparent, dependable, and secure p (Singh and Sisodia, 2021). Based on the survey done by analyzing 40 research papers, the architecture for tracking students' grade history is proposed in the next Section, dependable and secure performance (Singh and Sisodia, 2021).

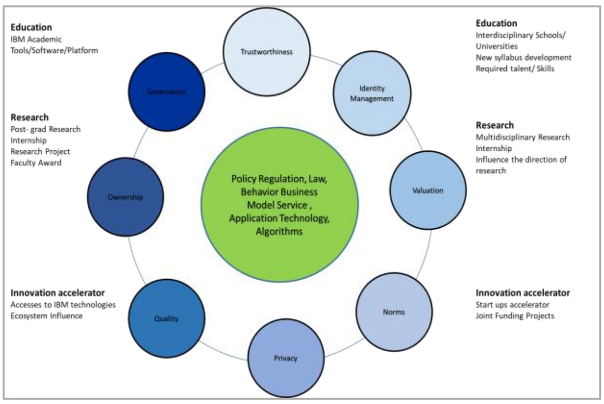

Fig. 3: Structure for Columbia-IBM center for blockchain and data transparency

Proposed Architecture for Tracking Students' Grade

Education is crucial for any country to advance; hence, it is typically the main priority for the majority of industrialized nations. Since education is crucial to any country's development, the majority of industrialized nations often give it the greatest priority. Although technology and the benefits it brings to education have advanced significantly in recent years, there is still a need to concentrate on the development of human resources through learning. Cryptography is fundamental (Bisheh Niasar *et al*., 2020; Mozaffari-Kermani and Reyhani-Masoleh, 2010; Elkhatib *et al*., 2024) to securing the data stored on the blockchain. Each transaction, including mark entries, is encrypted and linked to previous records, creating a secure chain that is nearly impossible to alter without detection. Public and private keys facilitate secure access and authentication, ensuring that only authorized personnel can modify or view sensitive information. Blockchain's decentralized nature allows for continuous monitoring of data across multiple nodes, making it easier to identify discrepancies or faults in the marks data. Any unauthorized changes or errors can be quickly detected through consensus mechanisms, which require agreement among nodes before any modification is accepted. This enhances the reliability of the marks management system, ensuring that all records are accurate and trustworthy. This combination of fault detection (Mozaffari-Kermani and Reyhani-Masoleh, 2010) and cryptographic security significantly bolsters the trustworthiness and resilience of the marks management system against fraud and data tampering. Keeping the students' grades confidential and tempered proof is challenging in a centralized System. To overcome the threat of changing the student's grade, smart contract-based architecture is proposed using blockchain. Figure (4) represents the three nodes of the architecture. The admin node can manage all the courses, students, and faculty members at the university. Student nodes can access the marks for enrolled numbers only. Only the faculty node is allowed to add the exam and student for their respective subject. Both the faculty and student nodes can track the grade history over the period. Each write operation is considered as a transaction and is stored on the block. Once the transaction is stored on the block, no one can change it. Thus, the security and integrity of the grades can be maintained.

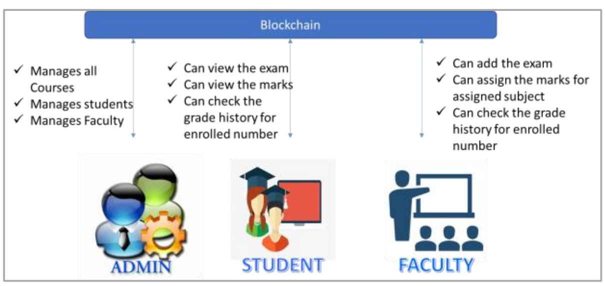

Fig. 4: Proposed framework for student marks management system

Limitations of Traditional Mark Systems and the Potential of Blockchain Technology in Academic Assessment

In traditional mark-management systems, student grades and other academic data are typically entered and kept in a centralized database or spreadsheet. This System can take a lot of time and be prone to mistakes, such as incorrect data entry or unintentional data loss. As opposed to this, a blockchain-based marks management system has the following benefits:

1. Immutability: The ability to produce an unchangeable, permanent record of data is one of the main characteristics of blockchain technology. Once a student's grades are entered into a blockchain-based marks management system, they cannot be changed or removed
2. Security: Because blockchain technology is decentralized, data is stored across a network of computers as opposed to being centralized in one place. Hackers will find it more challenging to infiltrate the System or steal student data as a result
3. Transparency: The usage of a public blockchain can make the System for managing marks more transparent. Access to the same information by students, parents, and teachers lessens the likelihood of disagreements
4. Efficiency: A blockchain-based marks management system can automate several processes, including calculating grades, confirming student identity, and making sure they have completed all course prerequisites. Time can be saved, and the possibility of mistakes is decreased
5. Portability: A blockchain-based system makes it simple to transfer student grades and academic records between schools, eliminating the need for labor-intensive and error-prone human data entry

As the traditional System is prone to errors as compared to blockchain based System, the frequency of errors can also be reduced using blockchain based system. In this Section, we have mentioned the different types of errors that can occur during mark entry and the frequency of each type of error for both traditional systems and blockchain systems. The dataset for manual marks entry is generated with the survey and past data. A smart contract-based System is developed for marks entry and is compared with the manual marks entry system. As each and every record updated by any of the nodes in block a blockchain-based System can be tracked, errors that occur during mark entry are much less as compared to a manual System. Transaction fees can be charged by the user, so it will, in turn, reduce the chances of errors while doing the entry in the System. Analysis of different types of errors like transposition errors, transcription errors, calculation errors, omission errors, and formatting errors is done for both of the System. Following are the types of errors for which the comparison is made:

1. Transposition error: When two characters or numerals are inadvertently switched or reversed in order, it is known as a transposition error. If the original text was "31", for instance, a transposition error could produce "31". This kind of error frequently occurs while manually entering data, where the data entry operator may inadvertently type the digits in the incorrect order
2. Transcription error: Mistyping of the digit is known as transcription error. Transcription errors can have serious consequences, as when students' grade information is transcribed incorrectly
3. Calculation Errors: Adding or subtracting the digits incorrectly can cause this type of error
4. Omission error: If the user forgets to enter the marks of the student, then it falls under the category of omission error
5. Formatting error: If the user enters the marks of students using the wrong units or decimal places, then it is known as a formatting error

The following steps have been followed to find the frequency of the errors that can occur during mark entry using a manual System:

1. Identify the types of errors that can occur during mark entry
2. Determine the probability of each type of error occurring. The probability of the errors can be estimated based on past experience, expert opinions, or statistical analysis
3. Calculate the frequency of each type of error by multiplying the probability by the number of marks that are being entered. For example, if the probability of a transposition error is 0.01 and there are 1000 marks being entered, the frequency of transposition errors would be 10
4. Add up the frequencies of all the types of errors to get the total frequency of errors. This will give an estimation of how often errors are likely to occur during mark entry in the traditional System

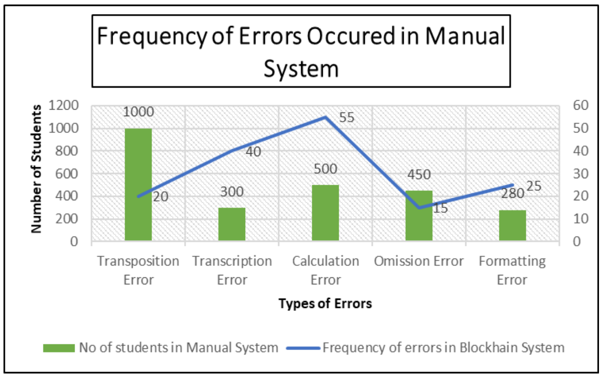

Fig. 5: Analysis of the frequency of errors in traditional system

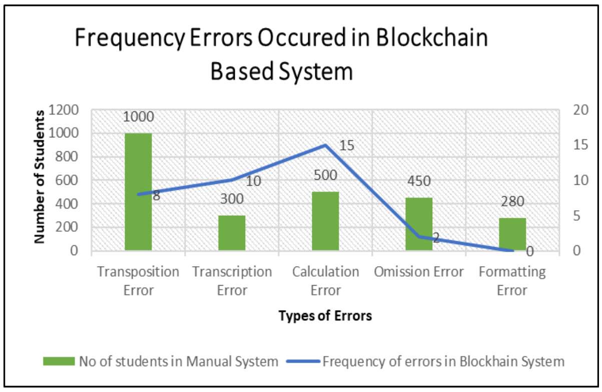

Fig. 6: Analysis of the frequency of errors in blockchain based System

Figures (5-6) depict the comparison of the frequency of errors in both manual and smart contract-based Systemsystems. Using a smart contract-based System, mark entry is done for the number of students as shown in the graph, and it is observed that the frequency of errors occurring is less in block a chain-based System. Based on the inputs for both manual and blockchain based Systemsystems, a comparison in terms of the percentage reduction of errors in blockchain based model is depicted in the below Table (1).

Table 1: Frequency errors occurred in the blockchain-based System (percentage comparison)

Error type	Manual System %	Blockchain system %	Percent reduction %
Transposition error	2.00	0.80	60.00
Transcription error	13.33	3.33	75.00
Calculation error	11.00	3.00	72.73
Omission error	3.33	0.44	86.67
Formatting error	8.93	0.00	100.00

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Methodology

Smart contracts are self-executing contracts with the terms of the agreement directly written into code. They run on blockchain technology, ensuring transparency, security, and immutability. This methodology outlines the approach to developing a smart contract for managing and entering student marks in an educational context.

The primary objectives of the smart contract for entering student marks include:

1. Data integrity: Ensure that student marks are accurately recorded and cannot be tampered with
2. Access control: Restrict operations to authorized faculty members only
3. Auditability: Provide a transparent record of all marks entered, allowing for easy tracking and retrieval

The proposed methodology outlines a systematic approach to developing a smart contract for managing student marks, emphasizing the importance of requirement definition, design, development, testing, deployment, and ongoing maintenance. By adhering to these steps, developers can create a robust and secure system that leverages the benefits of blockchain technology for educational institutions. This Section briefly depicts the steps required to implement the smart contract.

Define Requirements

The first step in developing a smart contract for managing student marks is to clearly define the requirements. This involves identifying the specific functionalities necessary for the System, including:

1. Adding students: The ability for authorized faculty members to register new students in the System
2. Creating exams: Faculty must be able to create exams associated with specific subjects and define parameters such as total marks and passing criteria
3. Entering marks: Faculty should have the capability to enter marks for students for each exam
4. Retrieving marks: The System must allow both faculty and students to retrieve and view marks and grade histories

Design the Smart Contract

Once the requirements are established, the next step is to design the smart contract. This involves:

1. Data Structures: Outlining the necessary data structures to manage the information about students and exams. For instance, a Student structure may include fields such as student ID and name, while an Exam structure may encompass exam ID, subject code, total marks, passing marks, and a mapping of student IDs to their respective marks
2. Function definitions: Defining the core functions for the smart contract, which should include methods for adding students, creating exams, assigning marks, and retrieving marks
3. Access control mechanisms: Implementing access control to ensure that only authorized faculty can perform certain actions, thereby maintaining the integrity and security of the data

Develop the Smart Contract

With the design in place, the next phase is to develop the smart contract using a suitable programming language, such as Solidity. Key tasks during this phase include.

Writing functions that manage the lifecycle of student marks, ensuring that operations such as adding students and exams are executed correctly. Incorporating checks to prevent duplicate entries, thereby enhancing data integrity and reliability.

Testing

Thorough testing is essential to ensure that the smart contract operates as intended. This involves:

1. Conducting tests in a controlled development environment, such as Remix IDE, to verify the functionality of all implemented features
2. Simulating various scenarios, including adding students and exams, entering marks, and retrieving data, to validate the contract's behavior under different conditions

Deployment

After successful testing, the smart contract is ready for deployment. This process includes:

1. Deploying the contract to a blockchain network, initially on a test net, to evaluate performance and functionality before moving to the main net
2. Ensuring that the deployment process includes proper configuration for access permissions and contract parameters to maintain security and functionality

Monitoring and Maintenance

Following deployment, ongoing monitoring and maintenance are crucial to address any potential issues. This includes:

1. Regularly monitoring the smart contract for bugs or unexpected behavior to ensure its reliability.
2. Updating the contract as necessary to enhance functionalities or rectify identified problems while considering that updates may require deploying a new contract to preserve the integrity of the existing data

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Experimental Analysis and Discussion

This Section implements a smart contract marks management system using Remix ide.

Remix IDE

One of the tools for adding contracts to the Ethereum network is Remix IDE. Remix IDE (Integrated Development Environment) can be used to create, test, and publish Ethereum Smart Contracts. Solidity is a high-level, contract-oriented language that can be used to construct smart contracts.

Experimental Setup

Experiments were performed on the proposed model using a machine with 32 GB RAM, 2 TB hard disk, Intel Core i5 processor, and 64-bit Windows operating system. Experiments were performed using solidity language with Remix IDE.

Proposed Smart Contract

The smart contract is developed for implementing the different functionalities and operations required to manage the students' grades. Szabo's idea of a "smart contract" is described as a computerized transaction protocol that carries out a contract's terms (Szabo, 1996). Three different nodes, as discussed in section 4, will perform different operations as per the privileges assigned to them. Remix IDE is a powerful open-source tool to develop smart contracts from a browser. It includes the functionality provided by the Solidity. We have used the functionality, which depicts how to restrict the use of certain functions. Only the faculty node will be allowed to access the subject data and assign the marks function.

The code depicts the three structures of the marks management system, i.e., Add student, add exam, and add faculty. The faculty node is responsible for adding the students and adding exams along with the subject code. The faculty must add student and subject details before entering the marks in the System.

Figure (7) depicts the add student function in the smart contract. Only the faculty node can add the student ID for their respective subject.

```
address private facultyAddress;
   uint256 studentCount = 0;
   mapping(string => mapping (string => uint)) exams_marks;
   mapping(string => Student) students;
   mapping(string => Exam) exams;
   mapping(string => bool) isExamExist;
   mapping(string => bool) isStudentExists;
   mapping(string => mapping (string => bool)) isMarksAssign;
   struct Exam {
      string EXAM_CODE;
      uint256 totalMarks;
      uint256 thresholdMarks;}
      struct Faculty {
      uint256 id;
      string UNIQUE_CODE;
      string subject;
```

Functions used in the marks entry system

```
function addStudent(string _collegeId)
      public onlyFaculty
      { require(!isStudentExists[_collegeId]);
         studentCount++;
         students[_collegeId] = Student(_collegeId);
         isStudentExists[_collegeId]=true; }
```

Code to add student

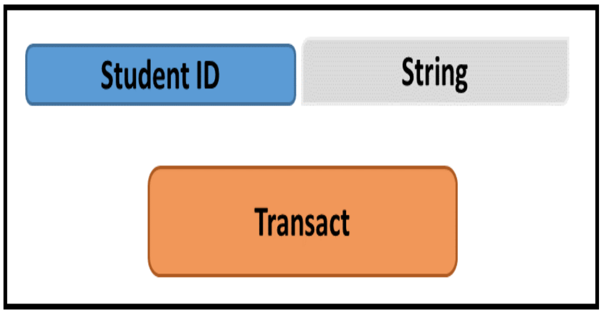

Fig. 7: Add function in the student management system

```
function addExam(string _EXAM_CODE, uint256
_totalMarks, uint256 _thresholdMarks)
public onlyFaculty {
require(!isExamExist[_EXAM_CODE],"Exam alredy
exists");
exams[_EXAM_CODE]=
Exam(_EXAM_CODE,_totalMarks,_thresholdMarks);
isExamExist[_EXAM_CODE]=true; }
```

Code to Add Exam Code and Marks

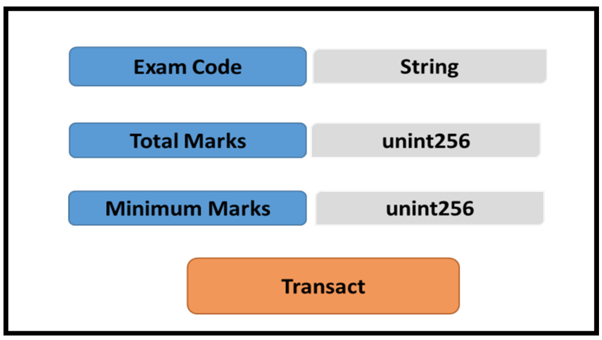

Fig. 8: Add function in the student management system

As represented in Fig. (8), the faculty node can assign the marks for their respective subject. Faculty must add the subject before performing the add exam operation. In case of multiple entries for the same subject, a message will pop up that the exam already exists. Faculty node must add the total and minimum or passing marks.

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```
//assignMarks
    function assignMarks(string _collegeId, string
_EXAM_CODE, uint256 _marks)
        public onlyFaculty {
            //checking is exam exists;
            require(isExamExist[_EXAM_CODE],"Exam not
found,enter valid exam code.");
            //checking is student exists

            require(isStudentExists[_collegeId],"Student not
found,enter valid student ID.");
            //checkchecking is marks already assigned

require(!isMarksAssign[_collegeId][_EXAM_CODE], "marks
alredy assigned, you cannot assigned again");

            isMarksAssign[_collegeId][_EXAM_CODE]=true;
            exams_marks[_collegeId][_EXAM_CODE] = _marks;

students[_collegeId].examMarks[_EXAM_CODE]=_marks; }
```

Code to assign exam code and marks to student

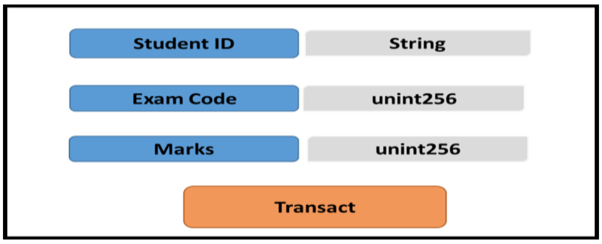

Fig. 9: Function to check that subject and/or student already exist

```
function changeMarks( string _collegeId, string _EXAM_CODE, uint256 _marks)
        public onlyFaculty {
        require(isExamExist[_EXAM_CODE],"this Exam not exist");
        require(isStudentExists[_collegeId],"this Student not exist");
        require(!isMarksAssign[_collegeId][_EXAM_CODE], "Marks already
assigned");
        assignMarks(_collegeId, _EXAM_CODE, _marks); }
    function getMarks(string _collegeId, string _EXAM_CODE)
    public view returns(uint256){
    require(isExamExist[_EXAM_CODE],"this Exam does not exist");
    require(isStudentExists[_collegeId],"this Student does not exist");
    require(isMarksAssign[_collegeId][_EXAM_CODE],"Marks already
assigned");                                                    return
exams_marks[_collegeId][_EXAM_CODE];     }
```

Code to retrieve exam code and marks to student

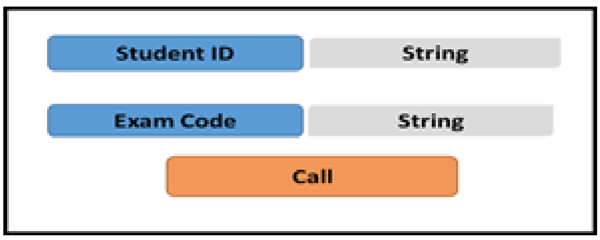

Fig. 10: Function to Get the Marks of the Student

After adding the student ID and exam in the System, the faculty node can assign the marks, and that is going to be stored on the private blockchain. No one can change the data, as blockchain is temper-proof.

As depicted in Fig. (9), one can check whether the student and/or subject already exists or not. As depicted in Fig. (10), the faculty node can also change the marks of the students as and when required. Anyone in the network with privileges can track the changed marks, and the changed marks are not going to be overridden. Both the student and faculty nodes can track the grade history. However, Smart contracts are vulnerable to various attacks, including reentrancy, integer overflow/underflow, and front-running. These exploits can lead to unauthorized fund withdrawals, manipulation of critical values, and financial losses for users. To mitigate these risks, developers should conduct regular audits, implement best practices, and ensure robust testing of their contracts. Also, the approach can still face the issue of preserving the privacy of the student marks. By using the k-anonymity-based enhanced privacy preserved model, the issue can be addressed in the future.

Conclusion and Future Enhancement

This study depicts the major applications of blockchain technology. Maintaining the data in a proof way in the education domain is a challenge. The technology's decentralization and data immutability bring a number of benefits that could alter how current systems conduct business. A Smart contract-based student marks management can help to manage the students' grade history in a decentralized manner. We have examined the current blockchain-based applications for certificate authentication and other applications in blockchain technology. Based on the survey and analysis, a Smart contract-based student marks management system is developed. In the future, the smart contract can be extended with more functions, and course certificates of the students can be generated. In addition, the latency and throughput can be improved. Moreover, the blockchain model can be integrated with the machine learning model in order to predict student performance. Given that privacy and security are paramount concerns regarding students' academic data, the current model can be enhanced by integrating a more robust privacy-preserving blockchain framework.

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Both the authors have equally contributed to this manuscript.

Ethics

This research was conducted in accordance with ethical standards and guidelines.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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