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Development of Educational Management Architecture employing Smart contract and Randomized mining in Permissioned Blockchain Environment

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Abstract Nowadays, the blockchain is applied in different sectors of our modern life such as business sector, government sector, online voting system, education sector, etc. Education system is one of the important and trending application areas of the blockchain technology. Traditionally, education system is dependent on record management and control system which are handled manually. It is very difficult to handle the consolidated data in the traditional centralized education management system and also hard to maintain trust among the users. The decentralized blockchain can be employed to tackle this situation. Many researchers proposed their methodology in this area but they mainly applied complex consensus protocols for mining or used private-public key pairs for security, which makes the system vulnerable while transferring the keys if it is not maintained properly. Furthermore, while the use of a private blockchain is much less common than that of a public blockchain, blockchain technology can be utilized to improve a private network as well. In this article, a simple and secured private blockchain network is presented to get rid from

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the problems of the traditional education management system.
A private blockchain network is proposed to apply within a university to manage data and control the whole system. In this proposed methodology, any complex mining algorithm is not required and the hashing is employed to provide a decent level of security. In addition, a smart contract-based student evaluation system is also presented for different institutional activities and to make the system more admissible. This methodology is segregated into four main steps - registration through admin, secure hash generation for security, transaction-based data collection, and smart contract for student evaluation. Through this proposed model, a secure education management system is furnished for decentralized data management along with maintaining trust among the users, which will increase the scope of the blockchain technology even further. The proposed methodology is compared with some existing blockchain based digital learning evaluation systems and proves its superiority over existing counterparts.

Keywords Education system, blockchain, secure systems, smart contract, hashing, randomized mining

1 Introduction

Through the use of decentralized and well-maintained data repositories[1], blockchain opens up new possibilities for achieving data integrity in many areas. Education system is one of the most vital sector among those. The data, such as student grades and evaluation records, is typically maintained in a centralized structured database in the traditional education management system. Data leakage, hardware failure, and damage are some security issues that could result from the high level of data centralization[2][3]. Because of this type of centralized storage, it is difficult for networks to sustain massive data transmission. As a result, the traditional system suffers from a variety of issues, such as poor efficiency, increased costs, inadequate utilization of data value, and others. A major weakness might be the super administrator who has access to data from the general administrative framework, learning, and research which violets the trust in the system. Additionally, there is a rising demand for data reliability and integrity, which centralized systems cannot ensure.[4]
After analyzing these problems, we determined that blockchain could be a suitable solution. Using decentralized blocks, the blockchain holds data that has been permanently encrypted and saved in different systems[5]. These decentralised blocks increase the security of each transaction, and the data stored within the system are immutable records which cannot be modified once they are created. Immutability is related to security[6], resilience and decentralization prevents data leakage, hardware failure, and data inefficiency.
Even though blockchain has these advantages it can make the model more complex and sometimes may not be free from vulnerability. These problems are the main motivations behind our research and we are trying to create a

simple but secure private blockchain to manage the education system. This paper enables instructors, students and other stakeholders to have more security over their personal data, the immutability of academic records, official documents, and certificates, and complete trust in the validity and reliability of network architecture[7]. The proposed model place a strong emphasis on data accessibility, consistency, and effectiveness while using a private blockchain network. The importance and sensitivity of student information in the education sector serve as the driving force behind this article[8][9]. Therefore, this method offers significant, secure, and transparent ways to create a system for managing and learning in the education system.

Section 2 describes blockchain and related technology. This section is further divided into two parts. Subsection 2.1 and 2.2 which gives a detail explanation of blockchain technology and related work of blockchain in the education system respectively. Section 3 is dedicated to propose our methodology. This section is divided into six parts: 3.1 Blockchain Model, 3.2 Registration process, 3.3 hash generation, 3.4 Education record manager, 3.5 mining algorithm and 3.6 Smart contract. In section 4 we discuss advantages and disadvantages of some research papers related to our proposed method. The section 5 is dedicated to the conclusion of the previously discussed sections.

2 Blockchain and Related Technology

Many researchers are now-a-days trying to implement blockchain technology in private networks. Education Sector is an area where blockchain technology can be used as private network as well as public network. In this section we are discussing the detail overview of blockchain technology and some research works on blockchain.

2.1 Blockchain Technology

Blockchain technology has become one of the most well-known and popular technologies in recent years[10]. One of the most important uses for Education Management Systems (EMS) is data security. Blockchain features visibility and sharing of data, both of which are essential for any EMS. Examination results and course registrations can be compared to financial transactions in that they cannot be changed or deleted once they have been entered into the system. Every time the entire chain of blocks becomes invalid if one block's content is tampered[11]. Information on the Blockchain is stored as hashes. Each block contains a series of transactions, a cryptographic hash value for the transactions, the version, and other crucial data for a blockchain,[12] similar to the hash value of the preceding block. So hash value plays the most important role to determine the relationship between two blocks.
In the blockchain data is stored as a series of blocks, with the hash value determining the specifics. Each block is connected to the one after it in a ledger,

which records all committed transactions[13]. All contacts and transactions between users of the distributed blockchain network are stored in the ledger. The longest chain is constantly growing as new blocks are consistently added to it. Each block also includes a message, current hash, previous block hash, date, block id, etc., depending on the application. The very first block without any parent is called genesis block.
All common transactions depend on a proper consensus protocol, which by default engages all stakeholders. Improved efficiency, increased security, and lower transaction costs are just a few of the noteworthy characteristics of this[14]. A blockchain protocol conducts the transactions provided by various users corresponding to their level of authority without requiring assistance from a third party.
From the time of registration to the time of graduation of a student, all the educational transactions that occur at universities requires a lot of money and time. In this environment, data integrity as well as security risks may be present[15].
The suggested architecture enhances security by using hashing technique and also the data is readily accessible due to decentralized data storage. The university's data is available on a blockchain for any interested parties to access. A successful implementation of the Education Management System has been made possible by immutability, sensitivity, and the way that blockchain saves data[16].Birth certificates, social security cards, student loans, and other values, along with transactional data like course registration and examination results,[17] can all be documented on a chain of interconnected blockchains.

2.2 Related Work of Blockchain in Education System

A variety of blockchain-driven intelligent education systems have emerged under the current educational theory. Article. [11] proposed a global higher education credit platform, named EduCTX. The ECTX tokens, which stand for the credits that students earn for successfully completing courses like European Credit Transfer and Accumulation System, will be processed, managed, and controlled by EduCTX.

Article. [18] proposes three models to use blockchain technology for implementing a functional Student Information System that keeps track of all transactions like student grades, faculty members' records, and course registration data, to avoid the position of a chief administrator.

In the Journal of Article. [19] suggests the early detection of diabetes using Blockchain technology which uses different machine learning classification algorithms to detect the disease earlier and secures patient Electronic Health Records in decentralised system.

Article. [20] present the preliminary steps of a study aimed at developing, testing, and deploying a supply chain collaboration platform based on blockchain technology.

Article. [21] Suggests a solution for the loss of data transparency beacause of single admin authority, that generate admin randomly after a certain duration called RandAdminSuite.

Article. [22] a blockchain-based encryption framework to offer security-based solutions Using a computational intelligence methodology. The suggested method yields better outcomes, with accuracy scores of 0.91 during validation and 0.93 during training.

Article. [23] involves four different stakeholders and investigates their increased satisfaction with diploma control, diploma veracity, and diploma credibility. The developed system was tested with external participants who were asked to adhere to a set of guidelines and fill out a survey to assess their perceptions.

Article. [24] proposed a block- chain 3.0-based architecture that converts learning process and experience data generated by teachers and various students into educational digital assets and implements the proper conformation and storage on blockchain.

Article. [25] proposed their model on 2021-2022 where they constructs a blockchain-based model for managing online learning data that addresses issues with trust authentication of curriculum resources and online learning data.

3 Proposed Methodology

Taking into account the aforementioned drawbacks of the paper we have proposed a private blockchain where we have used hashing technique to secure the network which decreases the complexity and also doesn't have any vulnerability as the hash is not shared with anyone. We also added a smart contract technology to create a student evaluation.
Our proposed method has five components as below and referes in Fig 1–

- Registration
- Hash generation
- Education Record Management (ERM)
- Mining algorithm
- Smart contract

These components are combined by the Blockchain models which consist of four nodes – Admin, Principal, Teacher, and Student (Fig 1).

We discuss each component in details with the appropriate pseudocode which drives the whole system.
In this research we use Postman software to develop and manage the network.

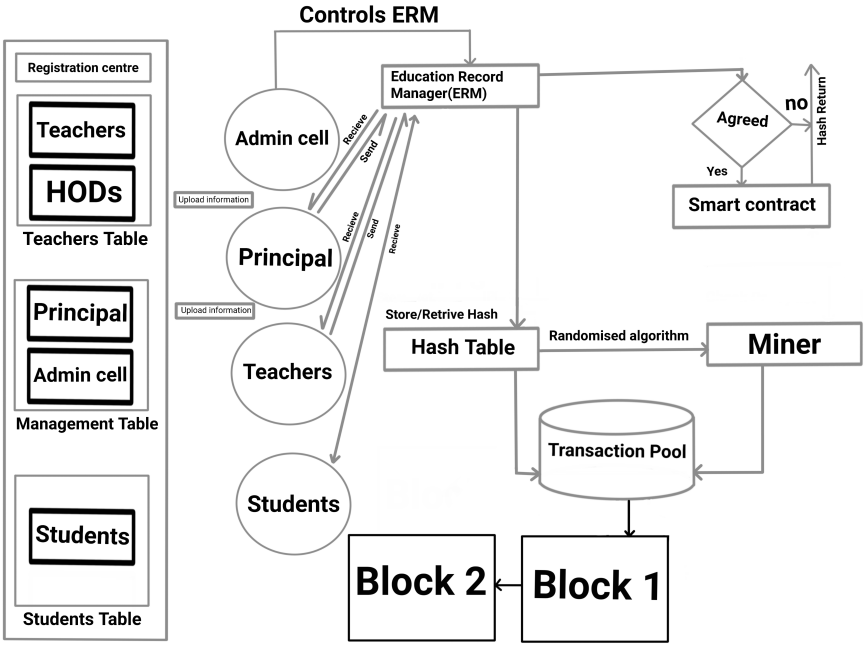

Fig. 1 Proposed System model of Blockchain Enabled Education Management System

3.1 Blockchain Model

In our proposed model we have four types of main nodes:

1. Admin
2. Principal
3. Teacher
4. Student

These nodes are created by the registration center using the basic information like Name, Email, DOB, qualification, etc. which will be stored in a database. In order to secure the data flow between these models every node has its authorities and limitations.

1. Admin Node
   – Permission of modification of his own basic information such as phone and address.

- Permission of modification curriculum.
- Permission of modification course list assigned to faculty members'.
- Initialize a transaction.
- Mine blocks.

1. Principal Node
   - Permission of modification students' and faculty members' basic information.
   - Permission of modification curriculum.
   - Permission of modification course list assigned to faculty members'.
   - Initialize a transaction.
   - Mine blocks.

1. Teacher Node
   - Permission of modification of his own basic information such as phone and address.
   - Access the certificate/student's transcript.
   - Permission of modification marks.
   - Initialize a transaction.
   - Mine blocks.

1. Student Node
   - Permission of modification of his own basic information such as mobile no. and address according to the guidelines.
   - Access only his own certificate transcript
   - Access faculty members' assigned course list.
   - Access marks.

Listing 1 Block creation

```
def create_block(self, previous_hash):
    transaction = self.transactions.pop()
    block = {'index': length(self.chain) + 1,
             'timestamp': str(datetime.now()),
             'previous_hash': previous_hash,
             'transaction': transaction
             }
    self.chain.append(block)
    return block
```

3.2 Registration Process

Registration is the first step in the proposed method. The main goal of registration center (RC) is to generate the nodes.

1. As Admin is the owner of this blockchain network; so, first admin creates the Network.

2. When other users (teachers and students) try to register for the first time they have to provide basic information for verification.
3. These details will be verified by the Admin and after verification they will join the network as a proper ledger.
4. After verification each user will be provided a unique id; Roll number for Students and teacherid for Teachers.

Listing 2 Registration process

```
def register():
    if id != 'admin':
        return "You are not eligible for the request"
    js = get_massage()
    _type = js['type']
    js.pop('type')
    _id = js['id'] if js.get('id') else js['roll']
    if _type == 'Student':
        Db.insert_one(js, 'Student')
    elif _type == 'Teacher':
        Db.insert_one(js, 'Teacher')
    else:
        print("invalid")
        return "Not valid type"
    Db.insert_one(post={"id": _id, "user": _type},
                  collection="Users")
    return "Successfully added to the database"
```

3.3 Hash Generation

After the successful registration the unique id will be converted into the hash value using SHA-256 hash function and stored in the admin database. This hash will be used for verification at the time of log in and any transaction by the node associated with the hash value. It also helps while selecting miner. The hash provides a secure end to end transactions between nodes. As the hash is not being shared with any participants of the network it provides additional security and data integrity.

Listing 3 Hash generation

```
def hash(self, block):
    encoded_block = block.encode()
    return hashfunction.sha256(encoded_block).hexdigest()
```

3.4 Education Record Manager

Education Record Manager (ERM) is one of the main part of our proposed system which is controlled by the Admin cell. When a node tries to make a transaction it sends a request to the ERM, if the request is valid then ERM send a validation signal which initiate the transaction. After successful transaction a hash is generated, which is stored in transaction pool by ERM.

Listing 4 Initiate transaction

```
def make_transaction():
user = Db.find_one({'id': id}, 'Users')
if user['user'] == "Student":
    return 'You are not eligible for this request'
js = get_massage()
transaction_keys = ['receiver', 'type']
if not all(key in js for key in transaction_keys):
    return 'Some elements are missing'
js['sender'] = id
blockchain.add_transaction(js)
r = {'sender': js["sender"],
     'receiver': js["receiver"],
     'transaction': blockchain.transactions
     }
requests.post("http://admin_port_address/get_miner", massage=r)

response = {'Message':
    'This transaction will be added to block
                    after verification.'}
return response
```

Here we are storing one transaction in one block; but if the system becomes larger we have to store multiple transactions in one block. Then we can consider using Markle Tree in the ERM to make the system more efficient.

Listing 5 Adding the new chain to the existing blockchain

```
def add_chain():
    if request.method == "GET":
        if id == "admin":
            block = {'index': length(blockchain.chain) + 1,
                     'timestamp': str(datetime.now()),
                     'proof': 1,
                     'previous_hash': 0,
                     'transaction': blockchain.transactions
                     }
            blockchain.chain.append(block)
```

```
            return block
        requests.post("http://admin_port_address/get_chain",
            massage={"id": id, "host": host, "port": port})
        return {"massage": "Request send"}
    else:
        js = get_massage()
       blockchain.chain = js["chain"]
        blockchain.transactions = js["transaction"]
        return js
```

The data for evaluation in the Smart Contract are provided from the databases connected to each node through the ERM.

3.5 Mining Algorithm

Pre-generated hashes of the nodes(except students, sender and receiver of the transaction) from the hash table of the admin cell runs through a Randomized Algorithm by ERM(Admin Cell) to generate the miner. The Randomized Algorithm is used to reduce the complexity of the system as we are using private blockchain network.

Listing 6 Randomized selecting algorithm

```
def select_miner(sender, receiver):
    return random.choice(all_host_except_sender_and_receiver)
```

Miner uses pre-defined verification rules to validate the transactions and stores the complete transaction to the newly generated block using the mining algorithm.

Listing 7 Get miner from the valid nodes

```
def get_miner():
    if id != "admin":
        return "Not eligible"
    if request.method == "GET":
        r = {}
        for i, m in enumerate(miners):
            r["miner-" + str(i)] = m
        return r
    js = get_massage()
    mine = select_miner(js["sender"], js["receiver"])
    miners.add(mine)
    print(mine)
    r1 = {'miner': mine,
          'POP': False}
```

```
        r = {'chain': blockchain.chain,
             'transaction': js['transaction'],
             'length': length(blockchain.chain)
             }
        requests.post("http://admin_port_address/update",
                      massage={"mine": r1, "chain": r})
        return r
```

Listing 8 MIning algorithm

```
def mine_block():
    if not id or id not in miners:
        return 'You are not eligible for this request'
    miners.remove(id)
    r1 = {'miner': id,
          'POP': True}
    if not blockchain.is_valid():
        return {'Message':
                'Last transaction is not valid.'}

    previous_block = blockchain.get_previous_block()

    previous_hash = blockchain.hash(previous_block)

    block = blockchain.create_block(previous_hash)

    response = {'message': 'Congrats, You mined a block',
                'index': block['index'],
                'timestamp': block['timestamp'],
                'proof': block['proof'],
                'previous_hash': block['previous_hash'],
                'transaction': block['transaction'],}
    r = {'chain': blockchain.chain,
         'length': length(blockchain.chain),
         'transaction': blockchain.transactions
         }
    trans = block['transaction']
    Db.insert_one(trans, 'Student_record')
    requests.post("http://admin_port_address/update",
                  massage={"mine": r1, "chain": r})
    return response
```

3.6 Smart Contract

Smart Contract is a technology which is used in blockchain networks to generate some specific output using some pre-defined conditions. Here we are

using smart contract to generate evaluations of students according to their academic details including marks and extra- curricular activities through the given rule(**??** for academic evaluation and 2 for extra-curricular activity):

Table 1 Academic evaluation

Grade	Marks range
Outstanding	80 to 100
Good	60 to 80
Average	25 to 60
Backlog	Below 25 height

Table 2 Extra-curricular activity:

Grade	No of activities
Outstanding	More than 15
Good	10 to 15
Average	5 to 10
No remarks	Below 5 height

The details are provided from the databases connected to each node Fig 2. The pre-defined rules are as follows:

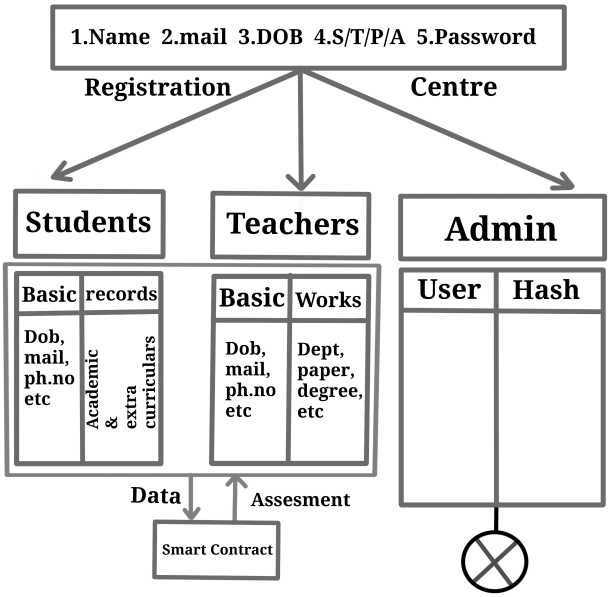

Fig. 2 Basic database architecture

The database is stored in the admin system and will gradually fill as the transaction of student records grows. Student and teacher database has two parts to store the static data like mail, phone number etc, and dynamic data like marks, paper publication etc.

The below flowchart[Fig. 3] explain the procedure of the smart contract architecture. We are using MongoDb online database to store and access the student records.
When any teacher or Admin wants to get an evaluation of the students they will call the smart contract with the student roll no. Smart contract first collects the student data from the database according to the roll no; and then that will be processed according to the condition given **??** and 2 and give the evaluation output. If the database is empty or the particular roll no is not found the smart contract will give a warning massage.

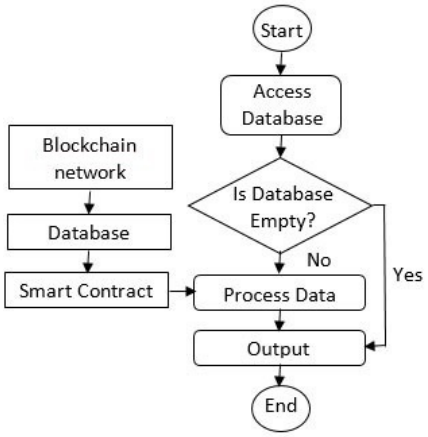

Fig. 3 Smart contract flowchart

4 Discussion

In this section we are developing a comparative study between our proposed methodology and some related works[18][19][20][21][23][11][25] as shown in Table 3. In this study we have tried to point out the differences based on five factors:

- Algorithmic complexity
- System complexity

Table 3 Comparison table of different paper

Paper no	ref no.	Time Complexity	Space Complexity	Architecture	Smart Contract	Security
1	Ref no.[18]	$O(n)$ & $O(n^2)$	$O(n)$	Wrong method: Blockchain creates a node.	No Smart contract	Use public private key;
2	Ref no.[19]	$O(1)$	$O(n)$	Public blockchain	Use Smart contract	Highly Secure use hash function for security.
3	Ref no.[20]	$O(n^2)$	$O(n)$	Hyperledger, No admin	No smart contract	No security algorithm specified.
4	Ref no.[21]	$O(1)$	$O(n)$	Random Admin generation	No smart contract	Use public private key; but add additional security
5	Ref no.[23]	$O(1)$	$O(n)$	Etherium Blockchain network	Use smart contract.	No additional security for data transfer.
6	Ref no.[11]	$O(1)$	$O(1)$	DPoS consensus protocol; No mining	No smart contract	Use public private key
7	Ref no.[25]	$O(n^2)$	$O(n)$	complex consensus protocol	use Smart contract	Use public private key pair.
8	3	$O(1)$	$O(n)$	Private network, Random algorithm to select miner	Use smart contract.	hashing technique is used for security

– Architecture
– Smart contract
– Security

In article[11] authors have used DPoS consensus protocol and they have used token exchange method to make any transaction or to verify any new institution who wants to join the network. As there is no mining algorithm used, it's not so complex though they have used public private key pairs as security.

Article[18] is a theoretical model. In this model they have proposed a private blockchain network. But as they said in the paper "Blockchain creates nodes" is not necessarily the proper terminology. In every network nodes are the stakeholders of the network and every node joins the network by themselves after proper verification.

In article[19] public blockchain model have used the highly secure hash function for security. They have also introduced the concept of smart contract.

Article[20] develops a private blockchain network of supply chain applications using Hyperledger platform. The transaction is encrypted and saved, being linked to the previous stock by hash coding, and therefore its history becomes immutable and inviolable. In this model, a smart contract is used to

trigger one or more transactions automatically which is planned or scheduled.

Article[21] used a randomized algorithm for admin generation. Compared to our model they don't have any fixed admin which makes their model more secure and improve the trust in the system. But They have used public private key pair for security that makes the algorithmic complexity $O(n^2)$. They also doesn't use any smart contract.

Article[23] uses Etherium blockchain which makes the algorithm complexity of $O(n^2)$. In this paper they have mainly focused on making a multi leveled advanced smart contract as Etherium blockchain comes with it's own security protocols, there is no additional security.

Article[25] is using public blockchain network with a complex consensus protocol. They have used a smart contract for verification and block generation. But block generation and verification is a feature of blockchain itself. So there is a room for improvement of this method. So we have, in our model, used smart contract as a student ecaluating system. Private public key pair is used as security, but as a two way process, it can be sometimes vulnerable. So instead of that we have used hashing technique for security.

In contrast to the previous mentioned paper we implement a private blockchain network which uses a simple randomized mining algorithm and also use a secure hashing technique for security which makes the architecture less time complex. We also implemented a smart contract for student evaluation.

The graphical comparison of time complexity and space complexity are given below in Fig.4 and Fig. 5:

5 Conclusion

In this model we introduces a private blockchain network where a secure hash generation is used instead of a cryptographic key pairs, which greatly reduces the complexity while having the decent level of security. As the mining algorithm we uses a randomized mining algorithm where every stake holder has equal chances (except sender and receiver) to be a miner, which once again reduces the complexity while marinating the data integrity and trust among the system. Our model also proposes a smart contact for student evaluation. As a base model it can further be modified to meet the requirements of certain universities. By adding a guest node it can be changed to a hybrid network or by changing it to a public network it will create a large education management system which integrates different universities to create a decentralized and secure data flow.
An education system manager (ESM) i.e universities can handle data in a way

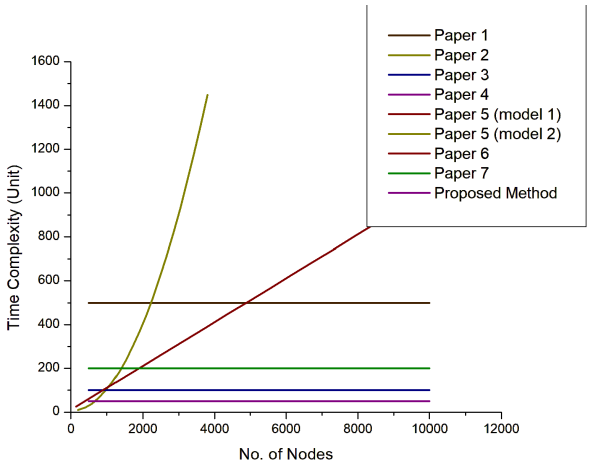

Fig. 4 Graphical comparison of time complexity of different paper

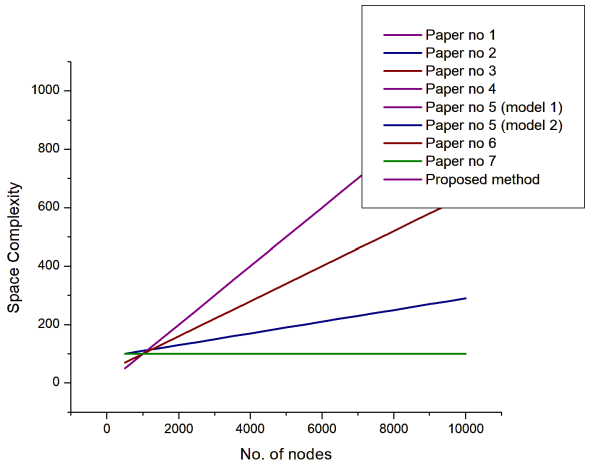

Fig. 5 Graphical comparison of space complexity of different paper

that greatly enhances security. The blockchain may incorporate decentralized data management to make it simpler to manage and transfer data. Another feature is that the records can introduce a reliable and highly trustworthy scheme for data access and storage, acting as a valid advisor for ESM maintenance.

Using machine learning technology, we can provide additional diversity in the evaluation system implemented in smart contract. So, we can say that this is a base model that will bring a new horizon to the traditional education management system and greatly increase the diversity and efficiency of the network.

References

1. Hada A. Alsobhi, Rayed A. Alakhtar, Ayesha Ubaid, Omar K. Hussain, and Farookh Khadeer Hussain. Blockchain-based micro-credentialing system in higher education institutions: Systematic literature review. *Knowledge-Based Systems*, 265:110238, 2023.
2. Yihuai Liang, Yan Li, and Byeong-Seok Shin. Private decentralized crowdsensing with asynchronous blockchain access. *Computer Networks*, 213:109088, 2022.
3. Ghassan Al-Sumaidaee, Rami Alkhudary, Zeljko Zilic, and Andraws Swidan. Performance analysis of a private blockchain network built on hyperledger fabric for healthcare. *Information Processing Management*, 60(2):103160, 2023.
4. Mengxiao Zhang, Jiamou Liu, Kaiyu Feng, Fernando Beltran, and Zijian Zhang. Smartauction: A blockchain-based secure implementation of private data queries. *Future Generation Computer Systems*, 138:198–211, 2023.
5. G. Thiraviya Suyambu, M. Anand, and M. Janakirani. Blockchain – a most disruptive technology on the spotlight of world engineering education paradigm. *Procedia Computer Science*, 172:152–158, 2020. 9th World Engineering Education Forum (WEEF 2019) Proceedings : Disruptive Engineering Education for Sustainable Development.
6. Lijun Xiao, Dezhi Han, Xiangwei Meng, Wei Liang, and Kuan-Ching Li. A secure framework for data sharing in private blockchain-based wbans. *IEEE Access*, 8:153956–153968, 2020.
7. Anatoly Konkin and Sergey Zapechnikov. Techniques for private transactions in corporate blockchain networks. In *2021 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (ElConRus)*, pages 2356–2360, 2021.
8. Dilip Krishnaswamy, Kanchan Chauhan, Aayush Bhatnagar, Shailesh Jha, Shobhit Srivastava, Dipender Bhamrah, and Manish Prasad. The design of a mobile number portability system on a permissioned private blockchain platform. In *2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)*, pages 90–94, 2019.
9. Fahad Ahmad Al-Zahrani. Subscription-based data-sharing model using blockchain and data as a service. *IEEE Access*, 8:115966–115981, 2020.
10. Iuon-Chang Lin and Tzu-Chun Liao. A survey of blockchain security issues and challenges. *Int. J. Netw. Secur.*, 19(5):653–659, 2017.
11. Muhamed Turkanović, Marko Hölbl, Kristjan Košič, Marjan Heričko, and Aida Kamišalić. Eductx: A blockchain-based higher education credit platform. *IEEE Access*, 6:5112–5127, 2018.
12. Naeem Iqbal, Faisal Jamil, Shabir Ahmad, and Dohyeun Kim. A novel blockchain-based integrity and reliable veterinary clinic information management system using predictive analytics for provisioning of quality health services. *IEEE Access*, 9:8069–8098, 2021.
13. K Palanivel. Blockchain architecture to higher education systems. *Int. J. Latest Technol. Eng. Manag. Appl. Sci*, 8:124–138, 2019.
14. AV Tolbatov, SV Agadzhanova, and VA Tolbatov. Using blockchain technology for e-learning, 1, no. 1, 2018.
15. M Meyliana, Cadelina Cassandra, Henry Antonius Eka Surjandy, Erick Fernando Widjaja, Harjanto Prabowo, and Charles Joseph. Defying the certification diploma forgery with blockchain platform: a proposed model. In *Proceedings of the International Conferences ICT, Society, and Human Beings 2019; Connected Smart Cities 2019; and Web Based Communities and Social Media 2019*, pages 63–71, 2019.
16. SMKVP Kumar, K Kiran Kumar, R Sai Krishna, and PSGA Sri. Incorporation of blockchain in student management system. *International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN*, pages 2278–3075, 2019.
17. Don Tapscott and Alex Tapscott. *Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world*. Penguin, 2016.
18. Sura I. Mohammed Ali, Haitham Farouk, and Hussien Sharaf. A blockchain-based models for student information systems. *Egyptian Informatics Journal*, 23(2):187–196, 2022.
19. Mengji Chen, Taj Malook, Ateeq Ur Rehman, Yar Muhammad, Mohammad Dahman Alshehri, Aamir Akbar, Muhammad Bilal, and Muazzam A. Khan. Blockchain-enabled healthcare system for detection of diabetes. *Journal of Information Security and Applications*, 58:102771, 2021.

20. Selmen BOUBAKER. Parisa DOLATINEGHABADI, Gael CLEMENT, Yassine HAMDAOUI, and Aissa BOUTALEB. A private blockchain platform to manage data exchange between supply chain partners. *IFAC-PapersOnLine*, 55(10):3316–3321, 2022. 10th IFAC Conference on Manufacturing Modelling, Management and Control MIM 2022.
21. Adam Mihai Gergely and Bogdan Crainicu. Randadminsuite: A new privacy-enhancing solution for private blockchains. *Procedia Manufacturing*, 46:562–569, 2020. 13th International Conference Interdisciplinarity in Engineering, INTER-ENG 2019, 3–4 October 2019, Targu Mures, Romania.
22. Taher M. Ghazal, Mohammad Kamrul Hasan, Siti Norul Huda Sheikh Abdullah, Khairul Azmi Abu Bakar, and Hussam Al Hamadi. Private blockchain-based encryption framework using computational intelligence approach. *Egyptian Informatics Journal*, 23(4):69–75, 2022.
23. Sérgio Guerreiro, João F. Ferreira, Tiago Fonseca, and Miguel Correia. Integrating an academic management system with blockchain: A case study. *Blockchain: Research and Applications*, 3(4):100099, 2022.
24. Junqing Li, Mo Lan, Ying Tang, Shichao Chen, Fei-Yue Wang, and Wei Wei. A blockchain-based educational digital assets management system. *IFAC-PapersOnLine*, 53(5):47–52, 2020. 3rd IFAC Workshop on Cyber-Physical Human Systems CPHS 2020.
25. Yaofei Wang, Qiurui Sun, and Rongfang Bie. Blockchain-based secure sharing mechanism of online education data. *Procedia Computer Science*, 202:283–288, 2022. International Conference on Identification, Information and Knowledge in the internet of Things, 2021.