International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V72I8P113

Volume 72 Issue 8, 112-127, August 2024

Original Article

An Automated Certificate Validation System Using Blockchain Technology for the Hiring Process

A. N. Shwetha[1], B. P. Ashwini[2], R. M. Savithramma[3], C. P. Prabodh[4]

[1,2,3,4]*Department of Computer Science and Engineering Siddaganga Institute of Technology, Karnataka, India*.

[1]*Corresponding Author : shwethaan@sit.ac.in*

Received: 19 October 2023 Revised: 23 February 2024 Accepted: 31 July 2024 Published: 28 August 2024

Abstract *- Blockchain is a digital, distributed and decentralized database that allows multiple users to store immutable transactions. The core structure of the blockchain contains a group of blocks in which every block can have a set of transactions. These sets of blocks are linked together by generating cryptographic hashes, which makes the data present in blocks immutable. The central authority is not required to manage data stored in the blockchain. A few prominent features of blockchain include Decentralization, Transparency, Security, Immutability and smart contracts. These key features made the blockchain popular in many domains. In this work, Blockchain is used as a secured database to store the academic certificates of students to streamline certificate validation in the hiring process. In the hiring process, validation of authenticity and certificates of students becomes time-consuming and difficult tasks for employers. Blockchain leverage can make this task easier. The universities can upload the E-certificates of graduating students to a blockchain, which will generate a digital transcript for each student. The generated digital transcript has to be communicated to respective students. Whenever the student applies for a job, the employer can validate the student's certificate by comparing the digital transcript received from a student with the certificates stored in the blockchain. If there is a match, it indicates that the certificates are authentic.*

Keywords *- Blockchain, Certificate validation, Hiring process, Cryptographic hashes, Smart contracts.*

1. Introduction

Blockchain is a distributed data record in a peer-to-peer network. Every user in blockchain can store digital records as a transaction in a blockchain. The data of the blockchain is not maintained in the central database; instead, it will be distributed across all nodes of a peer-to-peer network. Every user is able to access the information stored in the blockchain. None of the users can modify the transaction once it gets stored in a digital ledger. If the modification occurs in the transaction, it will be an error introduced and to reverse the occurred error, the new transaction needs to be added to the digital ledger. In that case, both transactions will be visible to users of the distributed ledger, and the intention of the malicious node will be showcased to all nodes of the p2p network. The set of rules called smart contracts has been written in solidity and will be present in blockchain. It will get executed automatically whenever a node of the blockchain network initiates a transaction. Blockchain provides greater trust because it is users only network, and there is no central database available to control data and operations. The users will have a trust that confidential data is exchanged only between users of the same network. Basically, blockchain is a collection of blocks. Each block contains the hash key of its own data, the hash key of the data and transactions present in the previous block and the information required to solve a puzzle for mining, like the nonce value in the header section. In the body part of a block, the set of digital records will be stored as transactions in the Merkle tree structure. The initial block of the blockchain is called the genesis block, which contains general information regarding the blockchain, such as the number of blocks in the blockchain, the size of each block, etc. The cryptographic hash key will be generated for the data stored in each block, and the hash key of each block is stored in the next block. So, when the data is modified in any block, there exists a mismatch between the old hash value and the newly generated hash value. So, modification can be rectified easily. Once the data gets stored in the blockchain, a copy of that will be shared across all nodes of a network, so it is impossible to delete or modify the data. Smart contracts contain the business rules for any blockchain application. When a transaction is done, it has to be verified by each user of the blockchain depending on previous history. If more than 51% of users validate the transaction, then it is authentic and eligible to be saved in the blockchain. Once a set of transactions is validated as authentic, the minor will store these transactions in a recent block and get rewarded. The copy of the freshly generated block will be attached to the blockchain and shared across all nodes of the network. The minors can be selected based on Proof of Work (POW) or Proof of Stake (POS).

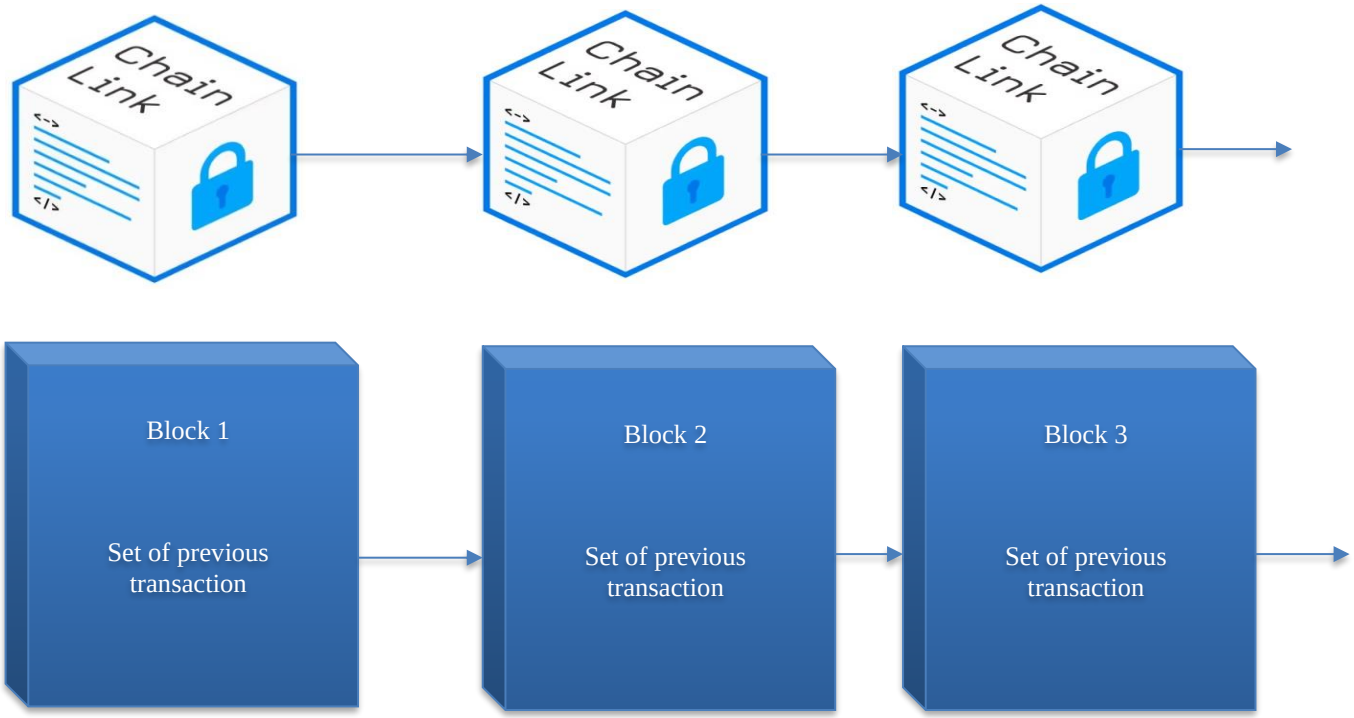

Fig. 1 General structure of blockchain

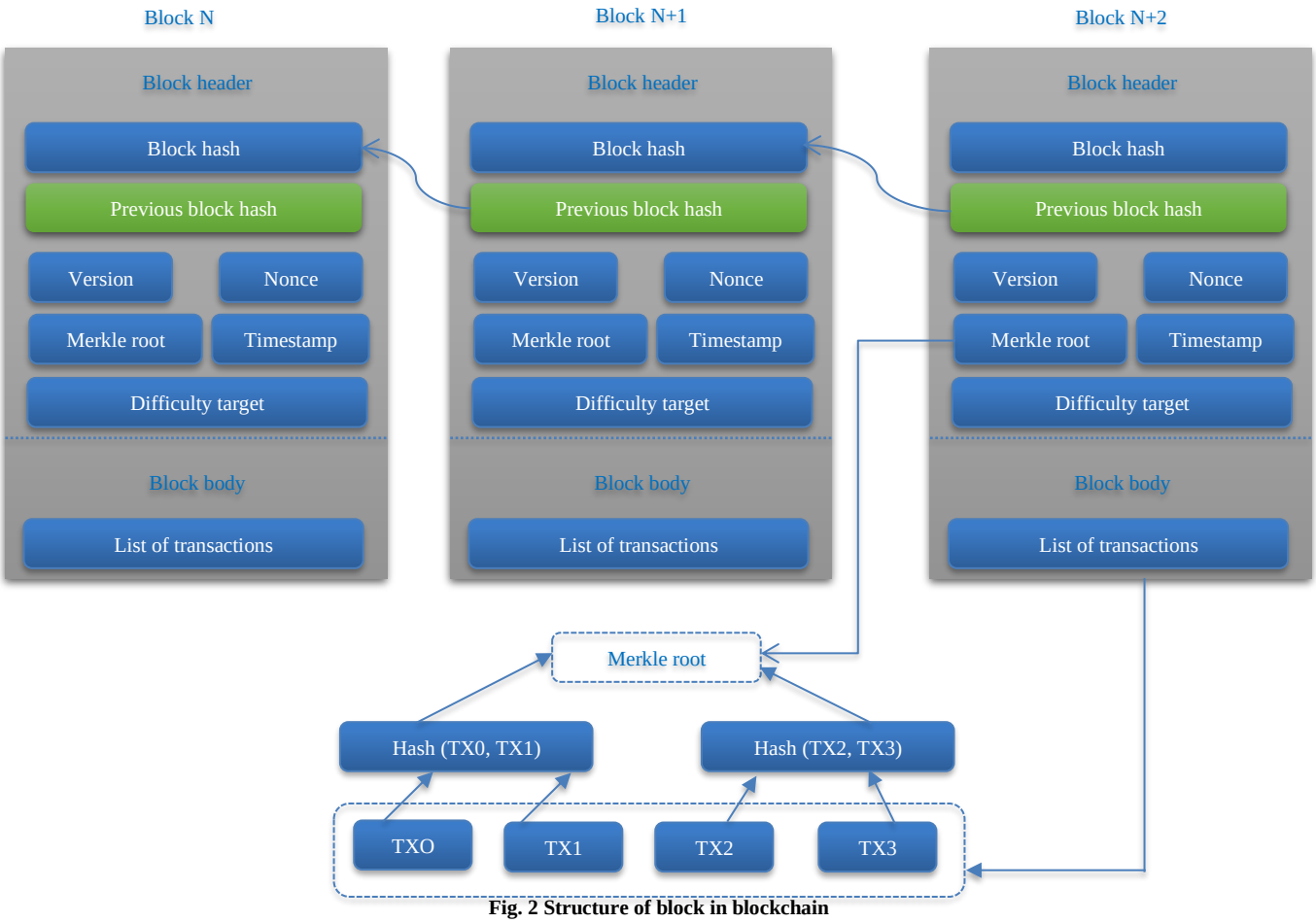

Fig. 2 Structure of block in blockchain

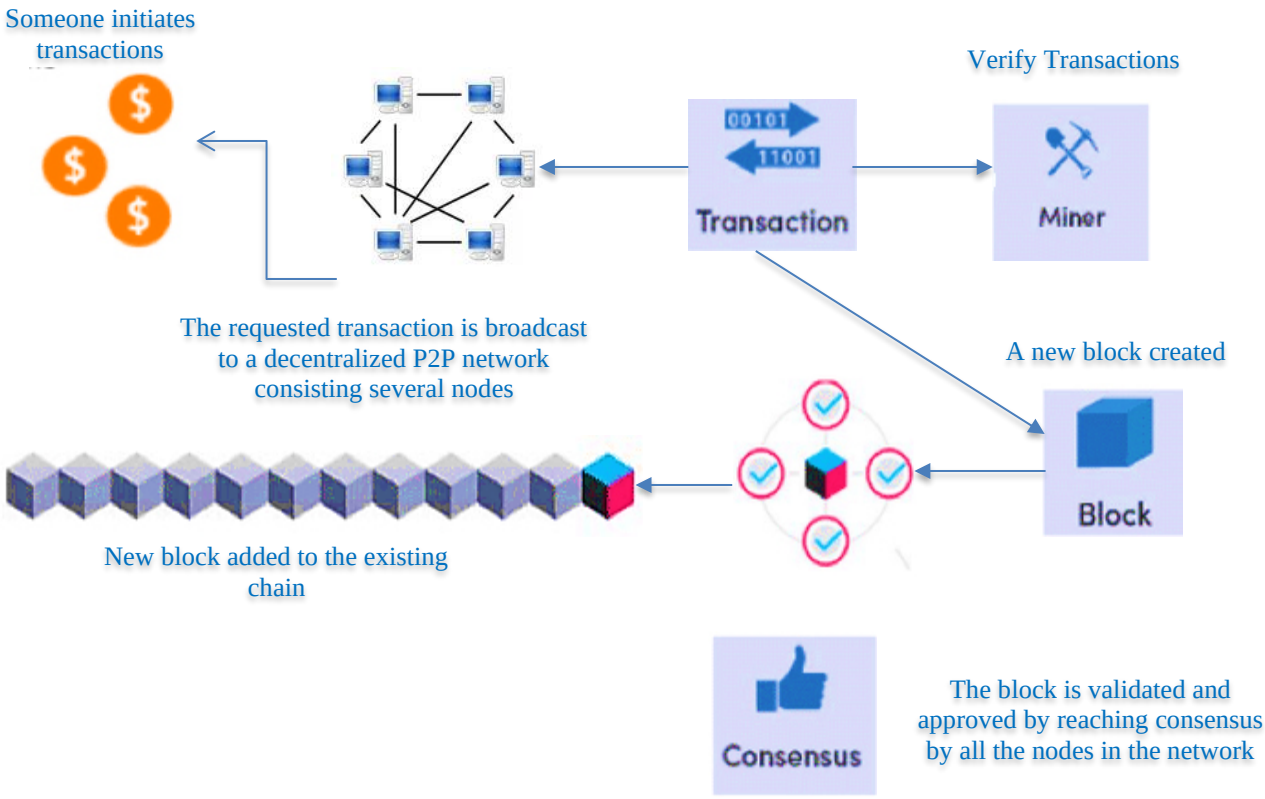

Fig. 3 Transaction flow in blockchain

The POW is a consensus mechanism to make all nodes have a common agreement to trust one another in a p2p network. Here all nodes try to solve a mathematical puzzle which requires more computational capability. The node which solves the puzzle first will be selected as minor. The minor validates the transactions, arranges them in chronological order, and creates a fresh block containing all validated transactions, and the fresh block gets added to the blockchain ledger.

The minor gets a reward for mining a fresh block. The disadvantage of POW is that it consumes more computational capability of a node to become a miner. To overcome the cons of POW, POS is introduced. In proof of stake, as the main suggests, the nodes who want to become validators deposit some amount of cryptocurrency. Then, an algorithm selects one node as a validator by considering the amount of stake and other related factors. The selected validator validates the transactions present in a pool and creates a fresh block. If the fresh block is accepted by all nodes in a network, then the validator can take back the staked cryptocurrency and also get rewarded. Merkle tree is also a binary tree created by the pointers to hash values. The leaf nodes contain the hash key of transactions. Two hash values are paired at the next level and compute the hash again. This process will be continued until the single hash value is computed comprising all transactions.

For example, consider four transactions named T1, T2, T3 and T4. The hash value can be computed for each transaction individually at the bottom-most level as per Equations (1) and (2)

$$H1 = \text{hash}(T1) \quad (1)$$

$$H2 = \text{hash}(T2) \quad (2)$$

Then, at the next level, two hash values are paired as in equation (3) to create a new hash value, and it continues till the root level.

$$H12 = \text{hash}(H1, H2) \quad (3)$$

As Blockchain technology is a leading technology, now educational institutions have started to adopt Blockchain ledger in their activities. There are a few use cases in educational institutions where we can adapt Blockchain technology. Some of them are mentioned below. One such use case is the intellectual property protection. Students and academicians publish their research work regularly. However, while conducting research, they do not have an idea regarding whether someone else is also working on the same problem statement or not. So, to help researchers, Blockchain can be adapted where the novelty work of a researcher can be posted on a regular basis and there is no restriction on the work where anybody can reuse it.

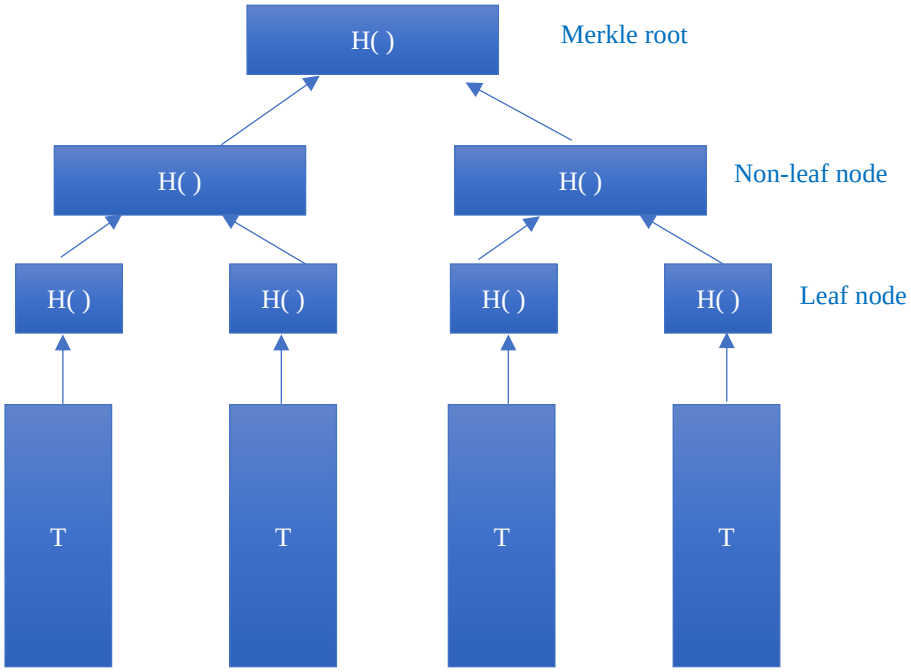

Fig. 4 Structure of merkle tree

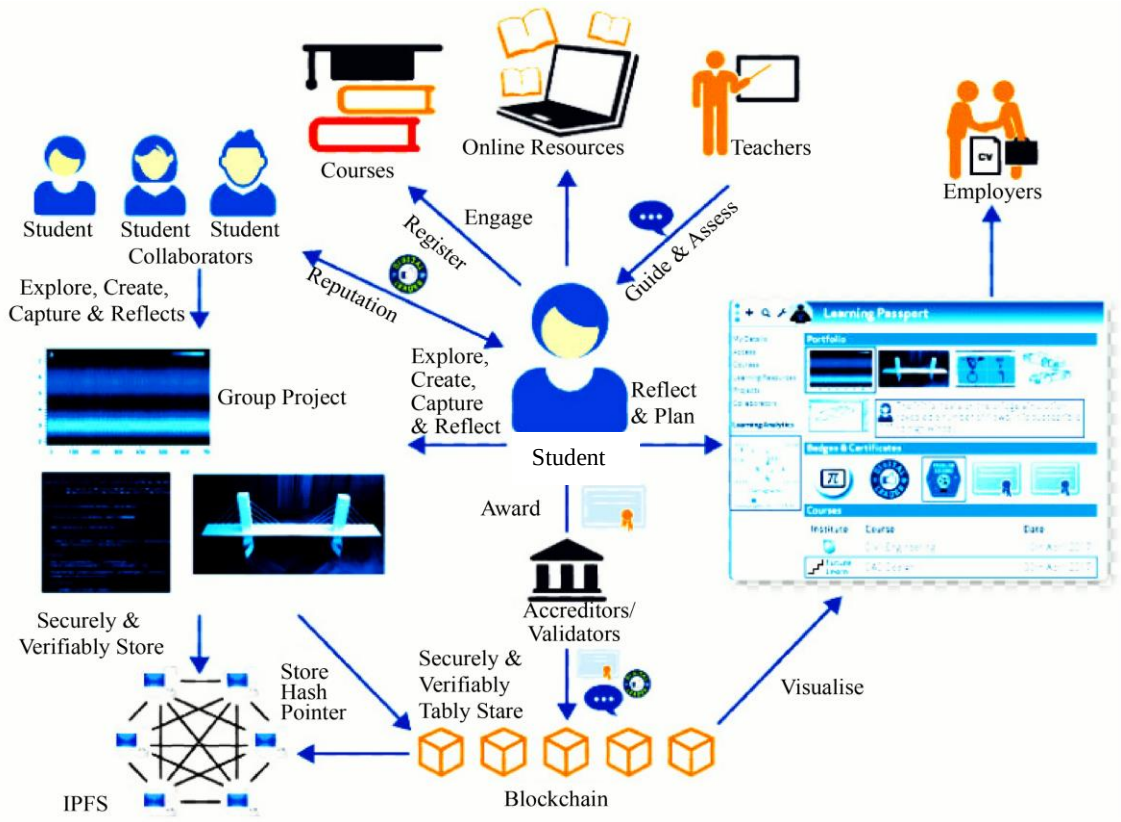

Fig. 5 Blockchain in the educational domain

So, the researcher who posted novelty work will get rewarded. Also, timestamps can be maintained for each posted work. The second testcase is to manage the student's academic records digitally in blockchain so that all the nodes can have access to them. The third use case can be during students join higher education in other universities. If a student joins for higher education in a foreign university, then the grading system or credit system will vary from university to university. Blockchain can be adapted here so that credit conversion rules can be implemented in smart contracts so that the job of students and higher education universities job will be easier. The fourth use case can be maintaining single and digital student identity in blockchain because, nowadays, managing and detecting student identity has become a tedious task. If it is maintained in a distributed ledger, every user can access it, and due to the presence of a single copy, confusion can be avoided. The traditional hiring process is done as follows. The candidates will upload their resume on the job websites or to company websites. The recruiters verify the resume, and if it matches the requirements of the job, they will be called for an interview. If a candidate gets selected, their certificates have to be verified by the employer manually.

The certificates of the employee to be verified can be their academic certificates, sports-related certificates, certificates related to a particular technology, competitions, etc. In this traditional approach, validating the authenticity and document verification is a tedious task. The traditional and manual way of certificate validation has drawbacks like inefficiency due to human errors, lack of time, delay and undetected fraud activities. Moreover, it is more time-consuming. To overcome these disadvantages, there is a need for an efficient, quick and secure certificate validation system. Blockchain technology emerged as a prominent solution for security, immutability, efficiency and transparency issues. A certificate validation system based on blockchain technology can change the way certificate validation systems in the hiring process. The goal of this work is to create an immutable and trusted database of certificates to ensure integrity and authenticity in the certificate validation process. By using blockchain smart contracts and digital signatures, the certificate validation system can be automated, which reduces the load on individual validators. It will also provide security and a well-structured solution, which will ultimately improve integrity, efficiency and reliability in hiring in today's competitive world.

2. Literature Survey

Zibin Zheng, Shaoan Xie and Hong-Ning Dai [1] provided an overview of blockchain architecture, consensus algorithms used, challenges in the adoption of blockchain, future trends and also recent advances in blockchain technology. A. Kosba, A. Miller, E. Shi, Z. Wen, and C. Papamanthou [2] presented a decentralized smart contract system to mask the sensible information present in the transaction from blockchain users. In the current scenario, the sensible detail of the transaction is stored in blockchain like the amount transacted from one account to another account. Such details are hidden in the proposed system. M. Sharples and J. Domingue [3] demonstrated the use of private blockchain in the education sector to upload and manage student information. The nodes responsible for mining in private blockchains of the educational sector are rewarded. Sriman B, Annie Silviya Sh, Santhosh Kumar E, Suryaa Narayanan K and Nishaalu S [4] proposed a blockchain application for industry 5.0 to implement smart contracts without any keys for distributed applications on Ethereum. The smart contract addresses are able to store the complete information regarding smart contracts.

Mara Florina Steiu [5] discussed various challenges that are to be faced while using Blockchain in the education sector and also discussed the various use cases that demand the applicability of Blockchain in the education domain. The major challenge identified here is data protection. Christian Delgado von Eitzen, Luis Anido Rifon and Manuel J. Fernandez Iglesias [6] analyzed that blockchain has proven its importance in the education domain and opens up various applications at various stages of educational area. Moreover, suggested that the adoption of blockchain in education can bring up more advantages and innovations in the education field.

Timothy Arndt and Angela Guercio [7] experimented with the implementation of blockchain in distance education so that it will help many aspirants who want to become educated, but it may not be possible due to some circumstances. Also discussed the pros of adapting blockchain in higher education. Jae Park [8] surveyed the various use cases of education where blockchain can be adapted and its effectiveness in improving the education of the current generation. Guang Chen, Bing Xu, Manli Lu and Nian-Shing Chen [9] focussed on the applications of blockchain technology in education and the problems which can be solved by the adaption of blockchain technology in the education sector. Skiba, Editor and Diane J [10] discussed what blockchain is and its advantages in healthcare and education.

Antonio Bartolome, Carles Bellver Torla, Linda Castaneda and Jordi Adell [11] attempted to make others understand blockchain and explored the advantages of blockchain ledger in the education domain. As we know, MOOC courses are very useful in distance education, and some institutions will consider MOOC courses in academics to award credits to students. However, the authenticity of learning materials in MOOC courses is a tedious task. Yonghui Dai, Guowei Li and Bo Xu [12] proposed a solution for such a problem: that is benefit of blockchain in MOOC courses removes the authenticity problem. The time required to mine a block in bitcoin is more compared to Ethereum. Daniel Kraft [13] used a poison process to reduce the time required to create a new block in bitcoin. Li Min and Ge Bin

[15] evaluated the effectiveness of online teaching using blockchain and proved that blockchain adoption can improve the quality of online education. As per today's education system, the curriculum structure, content, method of evaluation and teaching vary from institute to institute. Also, a few of the learning materials may not be available to each end user. To solve this non-uniformity, Bora Aslan and Kerem Atasen [16] proposed a solution based on blockchain for educational organizations to have uniformity in teaching across universities so that evaluation becomes easier.

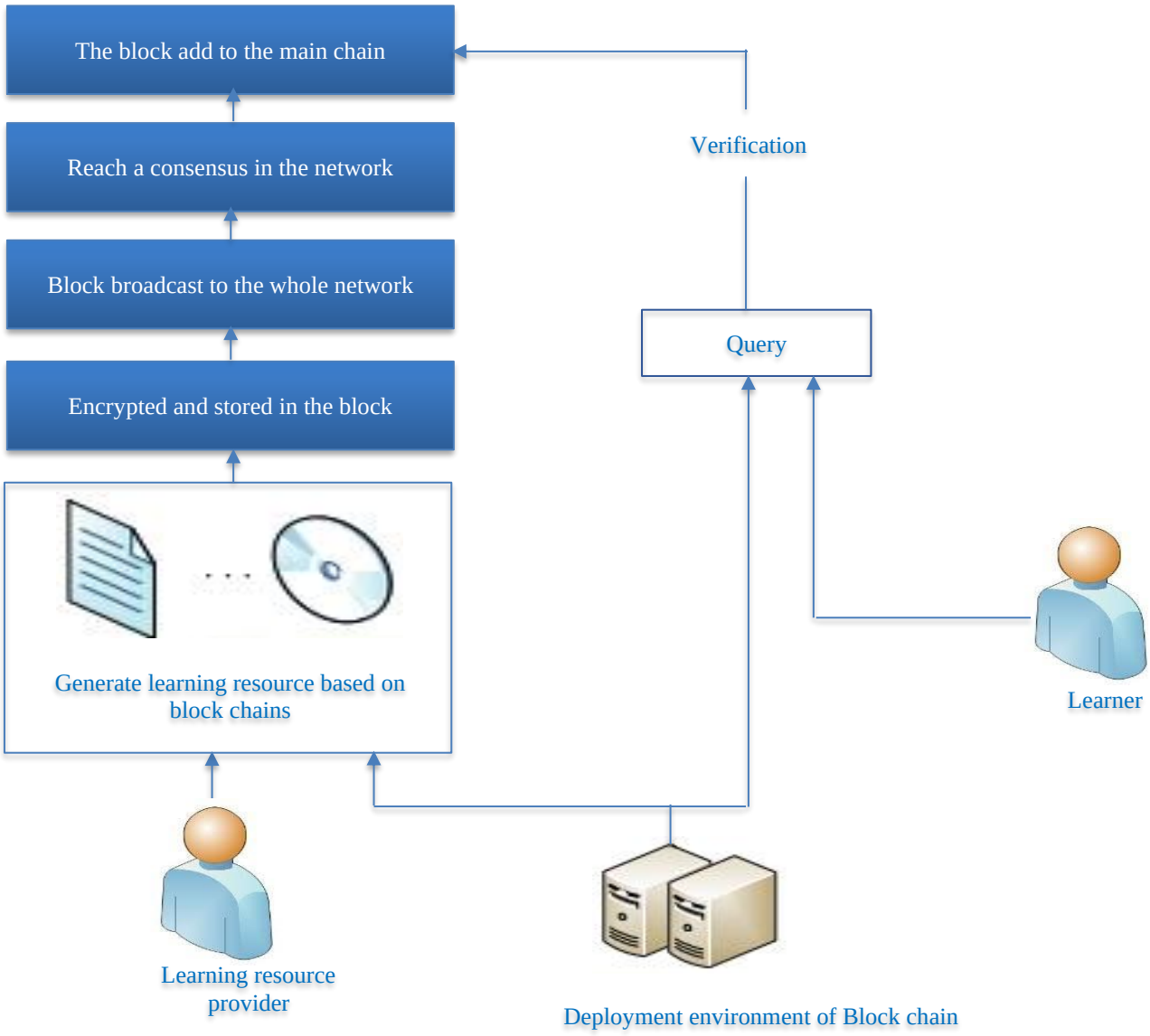

Fig. 6 Experimental validation framework

Table 1. Centralized applications and decentralized options

	CAPP	DAPP
Browsers	Chrome, Firefox	Brave
Storage Services	Dropbox, Yandex Disk	Storj, IPFS
Video and Audio Calling	Skype, Google Voice	Experty
Social Network	Facebook, Twitter	Steemit, Akasha
Messaging	Whatsapp, BIP	Status
Operating Systems	Android, IOS	EOS, Essentia, One, Nynja
Home Office Platforms	Up, Bionluk	Ethlance

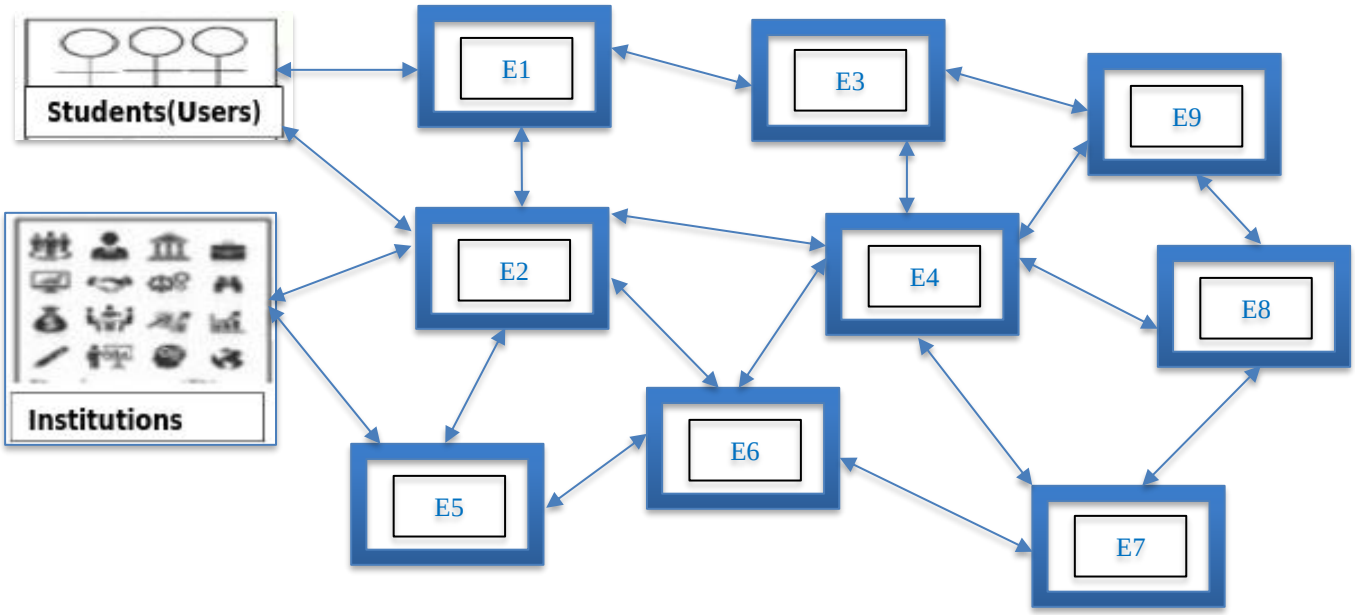

Fig. 7 Framework for blockchain-based E-Learning network

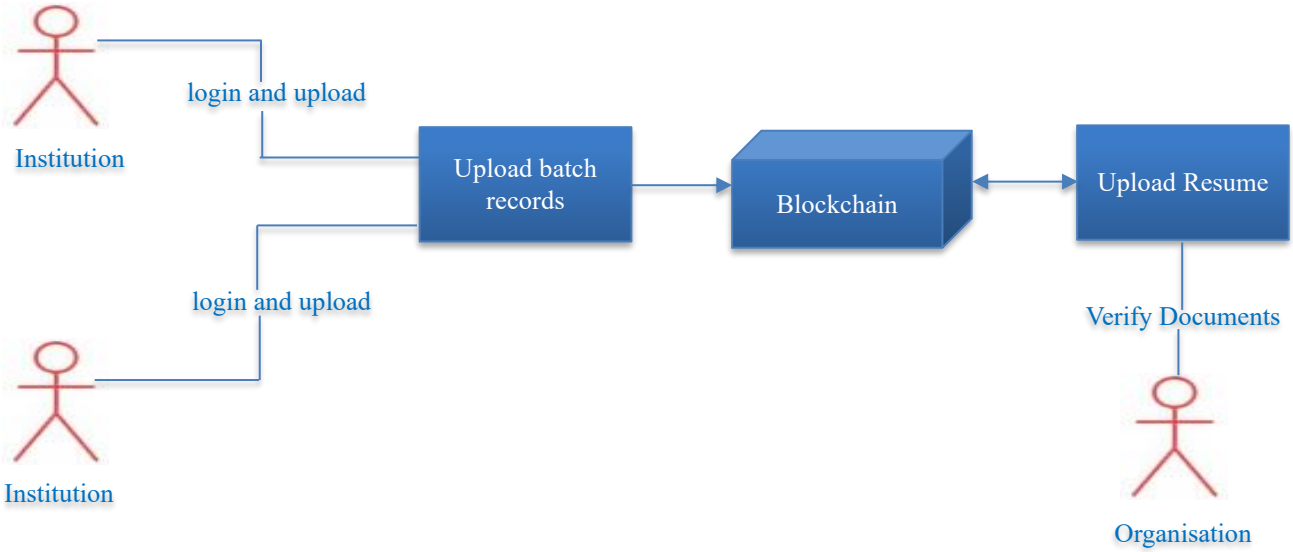

Fig. 8 Architecture of the proposed system

Robert D. Boyd and J. Gordon Myers[17] gave a new insight into education where the experiments were conducted to analyse the behaviour of students to solve a problem as a group work than solving it individually and also evaluated the effectiveness of both and showed that group work is able to give diverse solutions to a problem. Tao Li, B. Duan, D. Liu and Z. Fu [18] applied blockchain technology in outcome-based education so that student grades are converted to some values depending on their competencies and stored in blockchain. These values can be used for further evaluations. Arishi, H.A., Mavaluru, D. and Mythily, R[21] explored the ways in which blockchain can be adapted for virtual education.

Millicent Ubaka, Ambrose Azeta, Aderonke Oni and Hilary Okagbue[19] proposed the usage of the distributed ledger for safe and trustworthy data maintenance in educational sectors.

The preliminary or previous studies of this work discussed the applications of blockchain technology in different domains. In the survey, authors discussed the blockchain architecture, its advantages, its applications in various domains, challenges faced while deploying blockchain in various applications and the improvement in the efficiency of a few applications after adopting blockchain technology.

3. Design

The architecture of the proposed system is depicted in the Figure 8. The educational institutions and employers are provided with login credentials. The authorized person in the institution can login to the application and upload the certificates of students as batch records. For individual student certificates, a digital transcript will be generated, and it can be shared with the respective student. When a student applies for a job, he/she can submit a digital transcript along with a resume. To check the validity of certificates, employers can use the submitted digital transcript. If the data present in the digital transcript, which is submitted by the student and data present in the certificates of the respective student, which are stored in blockchain, match, then it indicates the information given by the student is authentic. One of the use cases considered in this work for blockchain in the education sector is maintaining certificates of students in blockchain and making the recruitment process easier. The diagram for the considered use case is depicted in Figure 9. Here, each university can maintain a private blockchain which contains the academic certificates of students belonging to their respective universities. Each student has a digital transcript as a piece of information regarding digital certificates stored in blockchain.

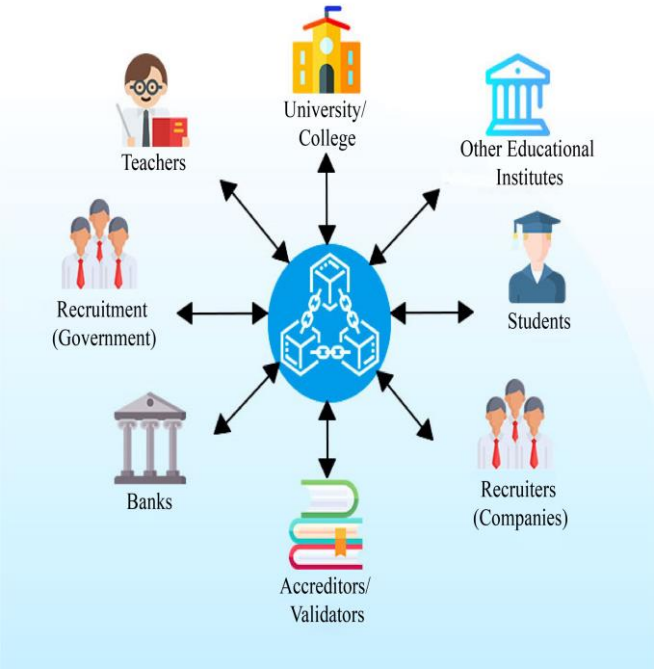

Fig. 9 Use case diagram

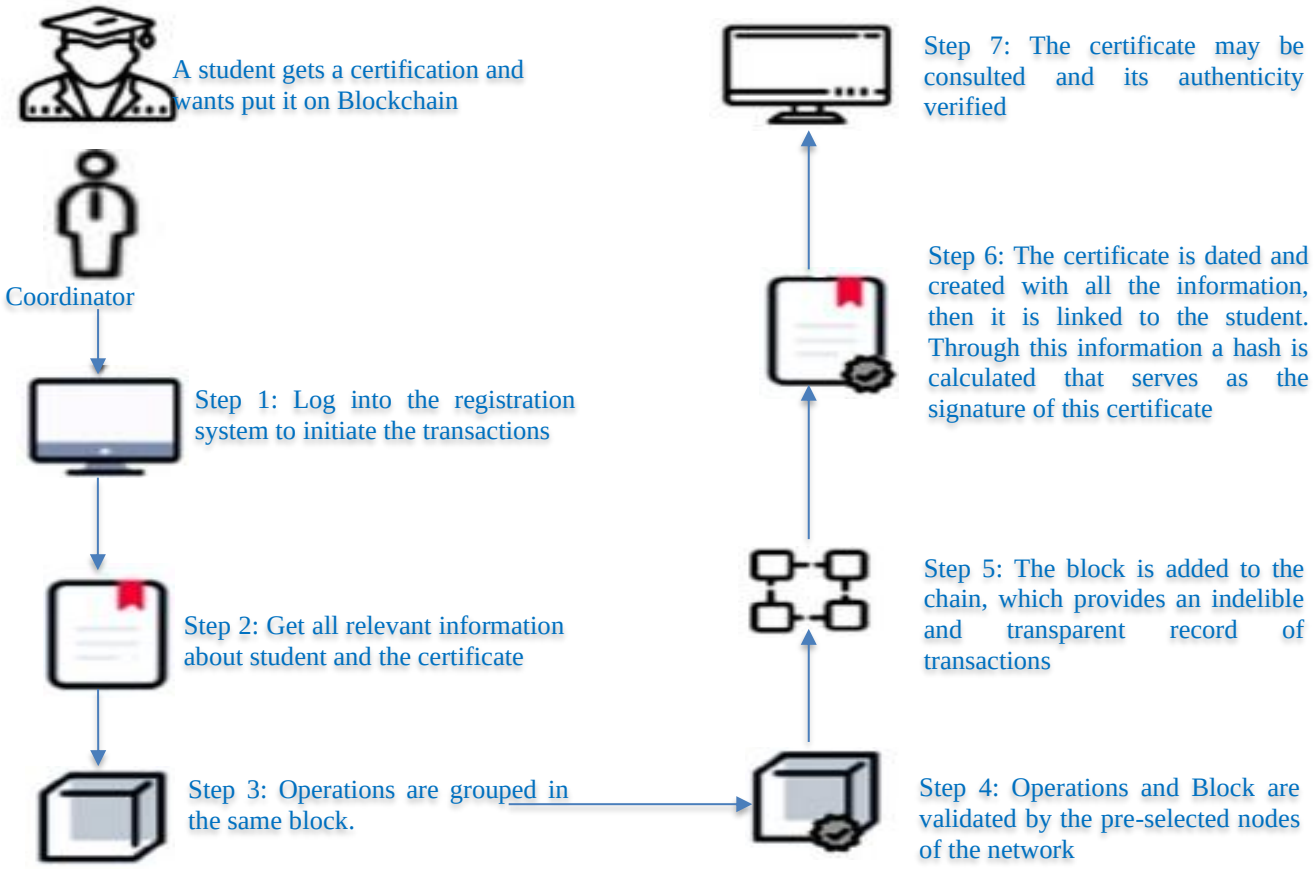

Fig. 10 Flow diagram

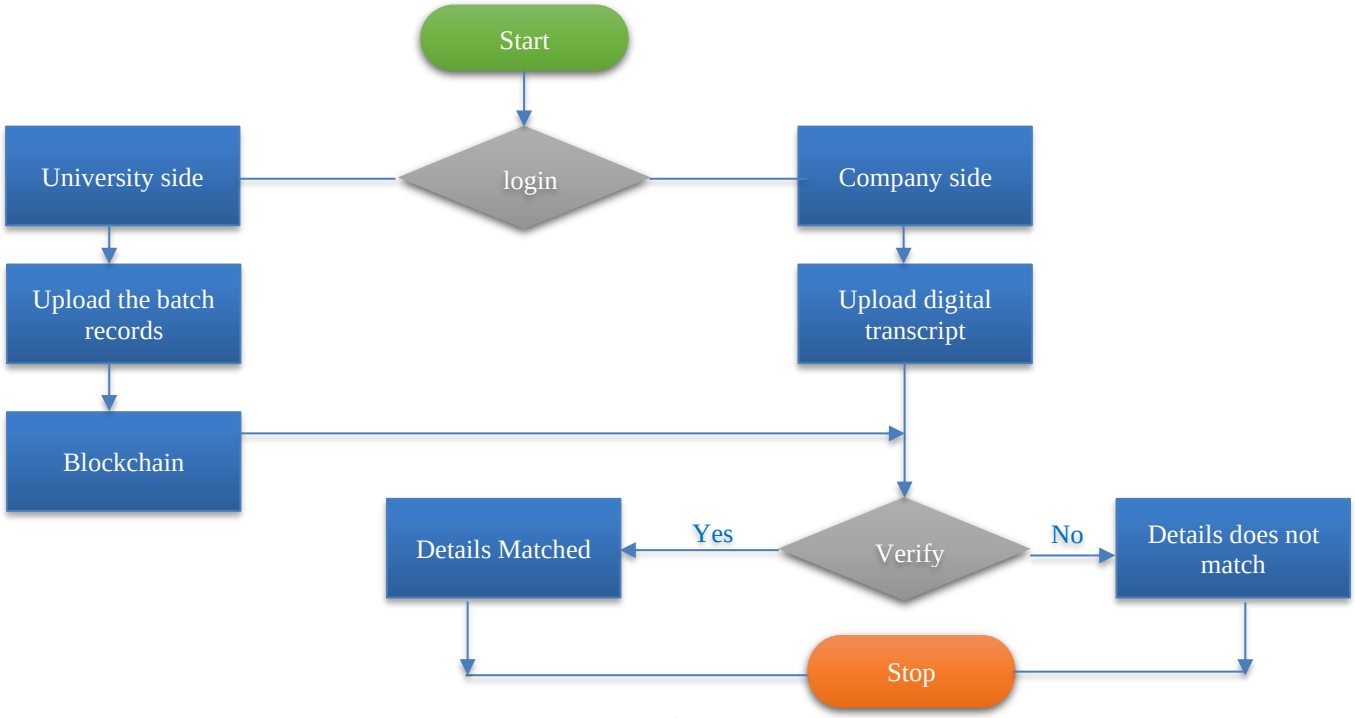

Fig. 11 Flow chart of the proposed system

By the time the student graduates, the university will issue the academic certificates to students, and students will submit these certificates when they apply for a job to the employers. Candidates appearing for placement activities conducted in college are requested to provide documents, and there are chances of providing fake or morphed documents to the hiring committee. In this trustless environment, it is necessary to identify the originals of the documents. So, a person is asked to verify all the documents submitted by candidates. The model verifies the document by comparing the resume uploaded by the third party. The blockchain model reduces the burden and saves time for the organisation by verifying the documents quicker and easier. Blockchain is known for its distributed ledger and security. We can access the data, but it cannot be modified, and we keep our confidential information safe by storing information in blocks. All the records of students would be uploaded on blockchain by the University, and these records can be accessible at any time, but they cannot be modified, and thus, all the records are secure. Each University can have its own blockchain and the records of the students studying in that particular organization will be uploaded.

Figure 11 depicts the flow of the project. The process begins depending on the person who is trying to utilize the next process will be continued. If the user is from the university, then he will upload the batch records to the website. Each document uploaded will reside in the block, and the collection of these blocks is linked by the hash value, resulting in the creation of a blockchain. It has key features like immutability, security and many more, which makes the verification easier and saves manpower. On the other hand, if the user is the company or organisation, he would upload the resume submitted by the aspirant and check if the details are correct. Using the records from the blockchain, the details will be checked, the corresponding result will be displayed, and the process will be terminated.

The university has to upload the csv file in a fixed format for a student getting graduate. Each instance may consist of the Unique Registration ID of a student, Name of Student, Cumulative Points, and batch. The digital transcript will be generated for every student as a JSON file. This digital transcript is shared with a student through email or any other communication medium. One digital transcript can be generated for one transaction, but it is efficient when we use one transaction for issuing a batch of transcripts. The Merkle tree is created consisting of transcript hashes by the framework, and the root of the Merkle tree will be stored in the message field. The digital transcript can be submitted to any employer or higher education institute by a student for verification. Then, the verifier can upload the digital transcript to the proposed system. Using the Merkle path stored in the digital transcript, the proposed system will recalculate the Merkle root for a specific batch of students. The recalculation of the Merkle root is a backward approach which involves multiple progressive recursive calls from the leaf to the root of the Merkle tree depending on the stored path information. Once the recalculation of the Merkle root is done, it is compared with the value stored in the blockchain by the system and also verifies whether an authorized institute signs it. This process is depicted in Figure 13.

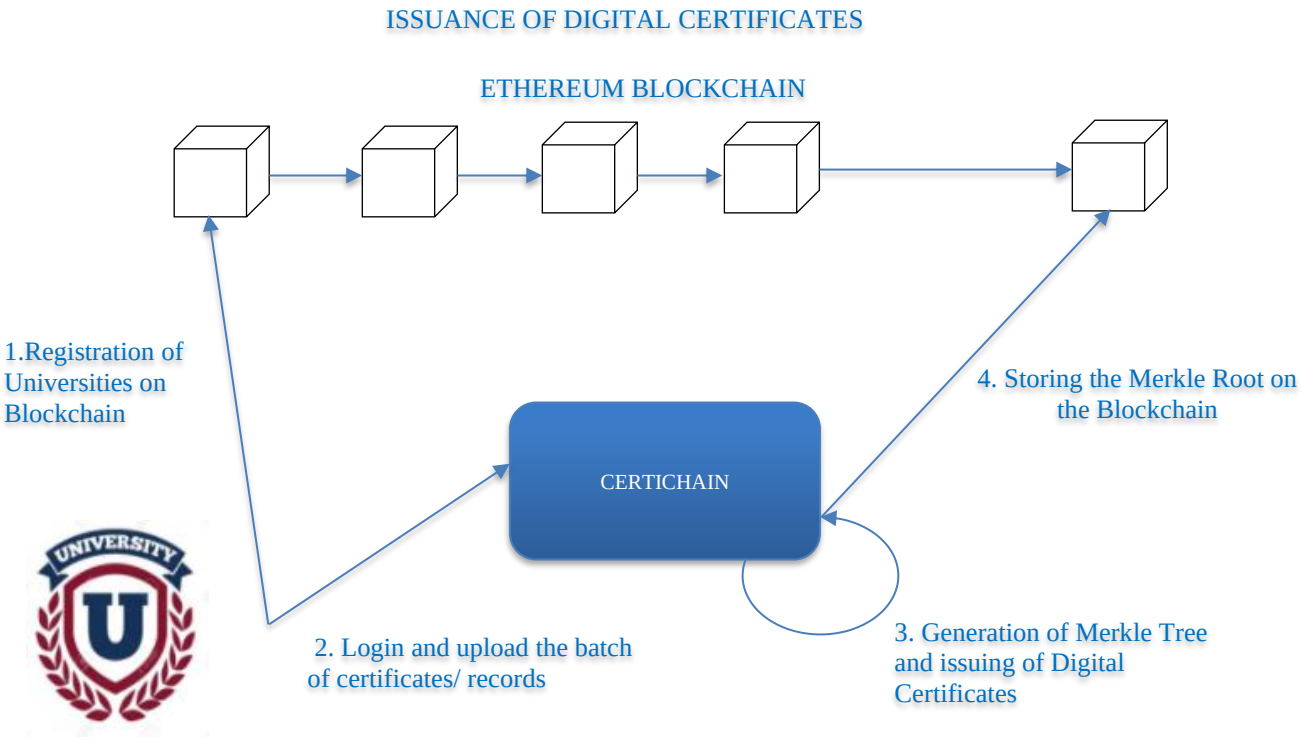

Fig. 12 Process to issue digital certificates

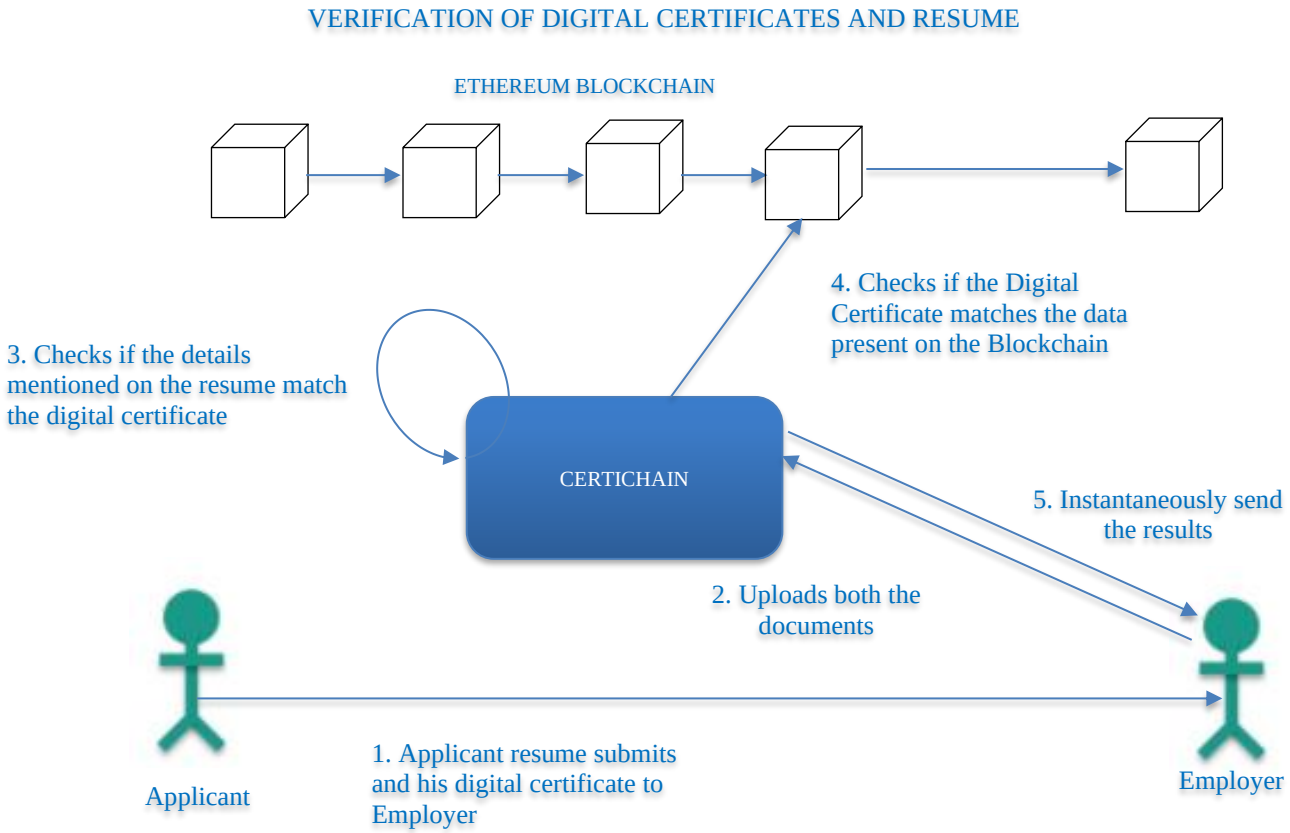

Fig. 13 Verification of digital transcripts for proposed framework

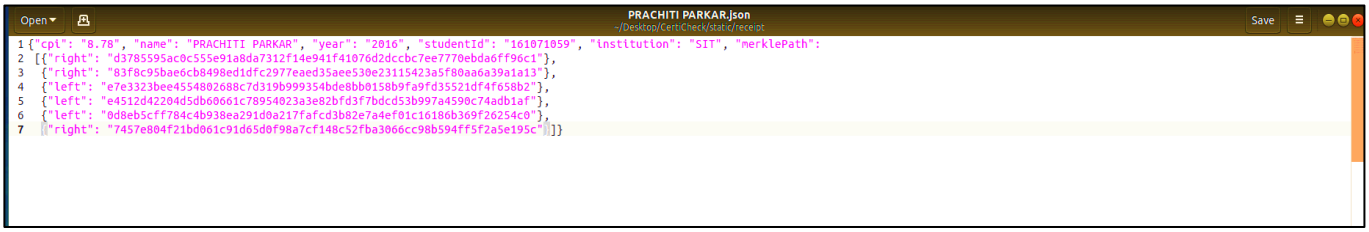

Fig. 14 Sample digital transcript generated for a student

4. Implementation and Results

The tools used in the implementation of the proposed system are mentioned below.

1. Ganache: Ganache is used which is widely used by developers to create private Blockchains. It is also used to test solidity smart contracts by running them on a private Blockchain in a local machine. Ganache supports development environments like Ethereum and Filecoin. It provides various features like creating new accounts, sending transactions and debugging capabilities. The results and discussion may be presented separately or in one combined section and may optionally be divided into headed subsections.

2. Solidity: Solidity is a programming language used to write smart contracts. It can be used for developing smart contracts on different blockchain platforms, most notably, Ethereum. It was developed by Christian Reitwiessner, Alex Beregszaszi and several former Ethereum core contributors to enable writing smart contracts on blockchain platforms such as Ethereum. The programs compiled by Solidity are intended to be run on an Ethereum virtual machine.

3. Python: Python is an interpreted high-level general-purpose programming language. Python's design philosophy emphasizes code readability with its notable use of significant indentation. Its constructs and object-oriented approach help programmers write code for small and large-scale applications.

4. HTML and CSS: The Hypertext Markup Language, or HTML is the standard markup language to display documents on a web browser. Cascading Style Sheets (CSS) is a style sheet language used for describing the presentation of a document developed in a markup language such as HTML.

4.1. Proposed Algorithm

Step 1: Python is used as the scripting language, flask as a frame work. Flask is developed using Python. It is categorized as a microframework because it will not require specific tools or libraries. When third-party functions are available, it does not require other components.

Step 2: The web interface starts running, and the user has to connect to ganache software. Firstly, the Institute admin /controller will log in to their account by entering their user name as the college name and password.

Step 3: The admin has to upload the details of the students in the csv format. The csv file contains the details of the student like Student ID, Name, CPI, year of graduation, etc. The details of each student are uploaded to the blockchain database, and the transaction will consume some amount of the Gas for the transaction. The details of each student will be converted into the JSON file format, where the details and the addresses of each node of the Merkle tree will be assigned. By Merkle tree root address will be fetched for the traversal of the tree.

Step 4: The verifier will upload the student's resume and JSON certificate for verification. The details in the resume will be extracted by the pdfminer package and compared against details in the JSON file to check validity. When the verifier uploads the applicant's resume, it parses the resume and extracts significant details like Name, CPI, College Name and Year of Graduation using NLP techniques, stores it in a JSON format, creates a hash of that and combines it with the neighboring hashes and generates the root hash.

Step 5: The digital transcripts submitted by the students will be verified. If the student details match or the details provided by the student to the hiring process to the details uploaded by the college controller. If the details match, then the verifier will get the pop-up as the details matched successfully. If the data is corrupted, then the details will not be matched, then the details that don’t match pop-up will be received.

One digital transcript can be generated for one transaction, but it is efficient when we use one transaction for issuing a batch of transcripts. The Merkle tree is created consisting of transcript hashes by the framework, and the root of the Merkle tree will be stored in the Message field. When the project is executed, the webpage of the proposed system gets loaded on the browser, and it is shown in Figure 15.

Fig. 15 Webpage front end

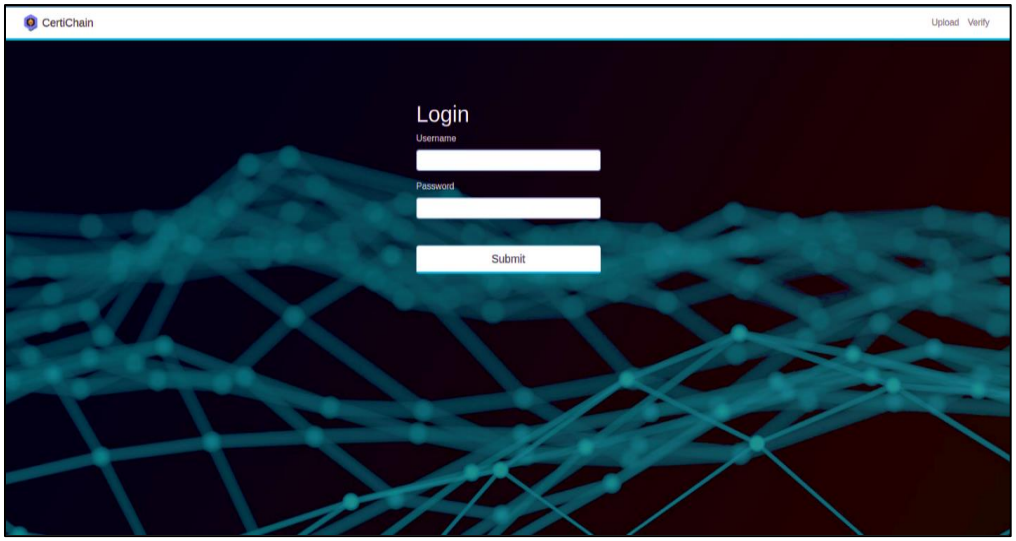

Fig. 16 Login page

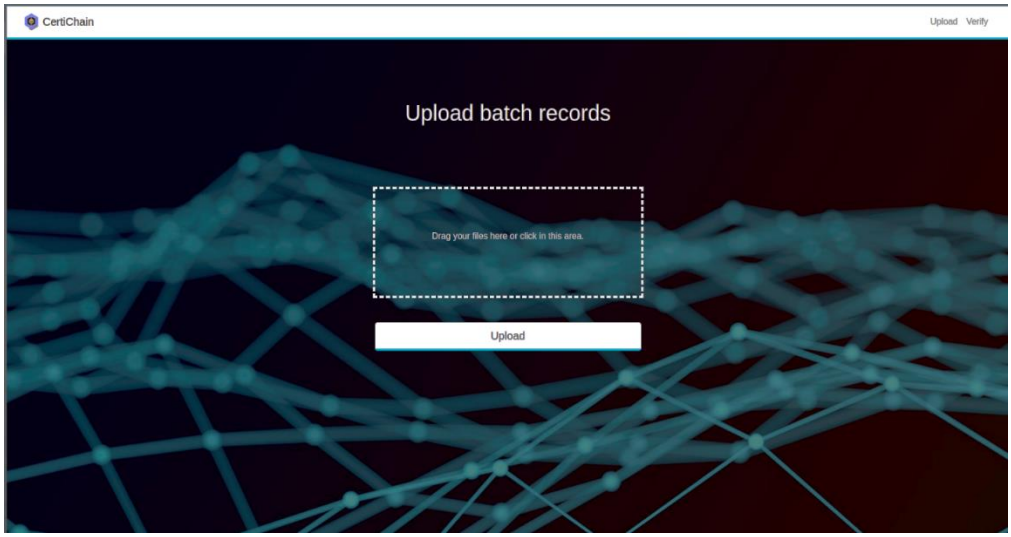

Fig. 17 Web page to upload student certificates

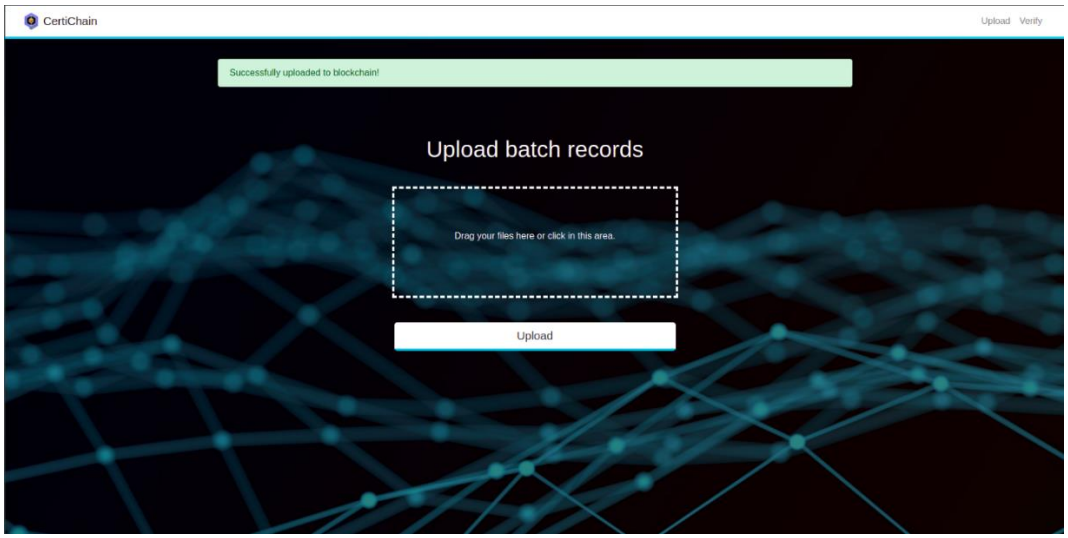

Fig. 18 Message for successful uploading of student certificates

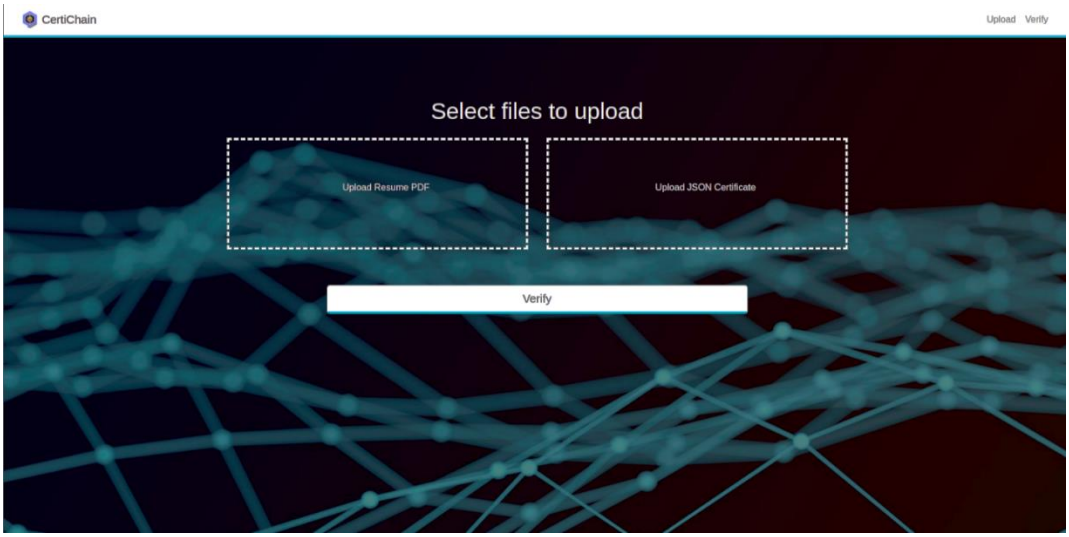

Fig. 19 Web page to upload resume and digital transcript

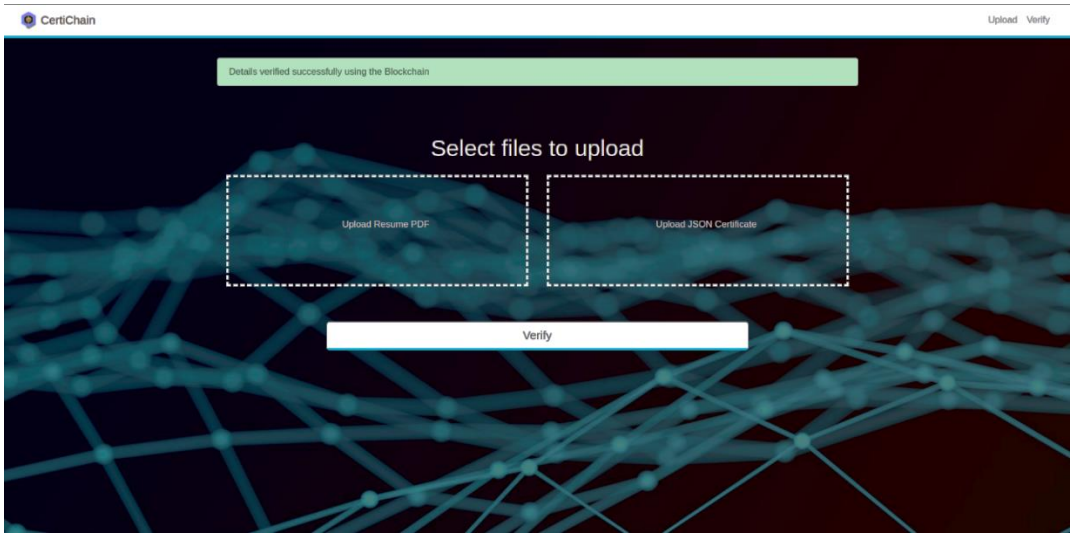

Fig. 20 Details of digital transcript matched with blockchain data

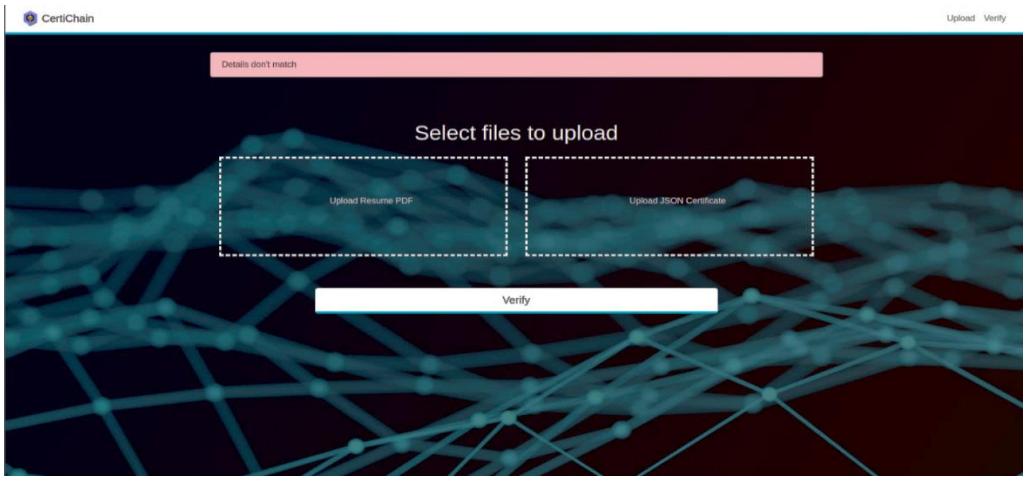

Fig. 21 Mismatch between details of digital transcript and blockchain data

A login page is created for users who want to verify the documents, such as Employers and to upload the documents on the blockchain, such as authorized people from university/college. Every user needs to log in with their respective username and password. University or School login to upload the documents of each student, whereas the organization login to verify the documents of the candidate. The Figure 17 shows the web page to upload student certificates as batch records.

A private blockchain can be used by each university, which contains students' certificates as blocks. After uploading each document, a pop-up comes up indicating that the file has been uploaded successfully onto to blockchain, which will be used in future for the verification process. Once the University has uploaded the certificates, they get stored on the blockchain and the transaction is recorded in the Ganache, which uses fake Ethereum coins it has. The company will upload the resume given by the candidate for the verification process. The digital transcript in the form of a JSON file needs to be uploaded, and then the details in the resume are matched with the contents of the JSON file and the corresponding result will be displayed. After the company side has uploaded the files, details from both files will be verified, and a pop-up of details verified successfully using blockchain can be seen if the details provided by the candidate are real. After the company side has uploaded the files, details from both files will be verified, and a pop-up of details that do not match can be seen if the details provided by the candidate are fake or morphed.

5. Testing

Testing is the process of identification of errors and debugging. Here, three types of tests are considered namely unit testing, integration testing and system testing.

5.1. Unit Testing

In unit testing, individual modules of the system will be tested to check whether the module is giving the intended functionality or not. Here, the considered test cases are

1. Institute admin Login

Unit to test : To verify whether the institute admin can log in to the system successfully.
Expected output : The admin has to log in without any errors
Pass or Fail : Pass

2. Uploading certificates by the organization

Unit to test : Verify that an institute admin can successfully upload certificates of students.
Expected output : The certificates are uploaded successfully without errors.
Pass or Fail : Pass

3. Verifier Login

Unit to test : To verify whether the verifier can log in to the system successfully.
Expected output : The verifier has to login without any errors
Pass or Fail : Pass

4. Uploading the student resume and JSON certificate for verification.

Unit to test : Verify that the verifier can successfully upload the student's resume and JSON certificate.
Expected output : The resume and certificate are uploaded successfully without errors.
Pass or Fail : Pass

5.2. Integration Testing

In integration testing, modules are combined together to check whether they are giving expected functionality in an incremented manner. Here, the considered test cases are

5.2.1. Generation of Digital Transcript

After uploading the student certificates by institute admin, for each student a digital transcript will be generated. This can be submitted to the employer for verification.

5.2.2. Details of Digital Transcript matched with Blockchain Data

After the employer has uploaded the files, details from both files will be verified, and a pop-up containing details which do not match if the details provided by the candidate are fake or morphed.

5.3. System Testing

System testing is used to check the overall functionality of the system. Here the system has to analyze whether the student certificates are genuine as per the certificates uploaded by the institute. Otherwise, it has to classify them as fake.

6. Conclusion

A blockchain-based model for educational certificate verification is proposed, which enhances the verification mechanism during the hiring process when the job is offered to the candidate, and there this will reduce the incidence of certificate forgeries or morphed certificates and ensure that the security, validity and confidentiality of the certificates will be improved. The advantage of the proposed model is that all the information that is required to validate and authenticate the certificate is hosted on the blockchain itself, and thus, the certificates won't be tampered with by any third party. In order to validate the certificate, the perspective employer need not contact the respective university at all. All they need to do is ensure that the digital transcript generated by the verification software matches the data contained in the blockchain. In future work, the certificates stored in the blockchain can be utilized by banks to sanction loans on the degree obtained by students and also for relevant applications in the educational sector.

References

[1] Zibin Zheng et al., "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends," *2017 IEEE International Congress on Big Data (BigData Congress)*, Honolulu, HI, USA, pp. 557-564, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[2] Ahmed Kosba et al., "Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts," *2016 IEEE Symposium on Security and Privacy (SP)*, San Jose, CA, USA, pp. 839-858, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[3] Mike Sharples, and John Domingue, "The Blockchain and Kudos: A Distributed System for Educational Record, Reputation and Reward," *11th European Conference on Technology Enhanced Learning*, pp. 490-496, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[4] B. Sriman et al., "Blockchain Industry 5.0: Next Generation Smart Contract and Decentralized Application Platform," *2022 International Conference on Innovative Computing, Intelligent Communication and Smart Electrical Systems*, Chennai, India, pp. 1-8, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[5] Mara Florina Steiu, "Blockchain in Education: Opportunities, Applications, and Challenges," *First Monday*, vol. 25, no. 9, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[6] Christian Delgado-von-Eitzen, Luis Anido-Rifón, and Manuel J. Fernández-Iglesias, "Blockchain Applications in Education: A Systematic Literature Review," *Applied Sciences*, vol. 11, no. 24, pp. 1-24, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[7] Timothy Arndt, and Angela Guercio, "Blockchain-Based Transcripts for Mobile Higher-Education," *International Journal of Information and Education Technology*, vol. 10, no. 2, pp. 84-89, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[8] Jae Park, "Promises and Challenges of Blockchain in Education," *Smart Learning Environments*, vol. 8, pp. 1-13, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[9] Guang Chen et al., "Exploring Blockchain Technology and its Potential Applications for Education," *Smart Learning Environments*, vol. 5, no. 1, pp. 1-10, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[10] Diane J. Skiba, "The Potential of Blockchain in Education and Health Care," *Nursing Education Perspectives*, vol. 38, no. 4, pp. 220-221, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[11] Antonio Ramón Bartolomé Pina et al., "Blockchain in Education: Introduction and Critical Review of the State of the Art," *Electronic Magazine of Educational Technology*, no. 61, pp. 1-14, 2017. [Google Scholar] [Publisher Link]

[12] Yonghui Dai, Guowei Li, and Bo Xu, "Study on Learning Resource Authentication in MOOCs Based on Blockchain," *International Journal of Computational Science and Engineering*, vol. 18, no. 3, pp. 314-320, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[13] Daniel Kraft, "Difficulty Control for Blockchain-Based Consensus Systems," *Peer-to-Peer Networking and Applications*, vol. 9, pp. 397-413, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[14] Q. Li, and X. Zhang, "Blockchain: Using Technology to Promote Openness and Credibility in Education," *Journal of Distance Education*, vol. 35, no. 1, pp. 36-44, 2017. [Google Scholar] [Publisher Link]

[15] Li Min, and Ge Bin, "Online Teaching Research in Universities Based on Blockchain," *Education and Information Technologies*, vol. 27, pp. 6459-6482, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[16] Bora Aslan, and Kerem Atasen, "A Blockchain Based Lifelong Learning Platform: The Smart University," *MANAS Journal of Engineering*, vol. 8, no. 2, pp. 151-154, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[17] Robert D. Boyd, and J. Gordon Myers, "Transformative Education," *International Journal of Lifelong Education*, vol. 7, no. 4, pp. 261-284, 1988. [CrossRef] [Google Scholar] [Publisher Link]

[18] Tao Li et al., "Design of Outcome-based Education Blockchain," *International Journal of Performability Engineering*, vol. 14, no. 10, pp. 2403-2413, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[19] Millicent N. Ubaka-Okoye et al., "Blockchain Framework for Securing E-Learning System," *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 9, no. 3, pp. 2933-2940, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[20] Matthew B. Hoy, "An Introduction to the Blockchain and its Implications for Libraries and Medicine," *Medical Reference Services Quarterly*, vol. 36, no. 3, pp. 273-279, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[21] Hamzah Ali Arishi, Dinesh Mavaluru, and R. Mythily, "Blockchain Technology and its Applications for Virtual Education," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 10, no. 13, pp. 1780-1785, 2018. [Google Scholar]

[22] Han Sun, Xiaoyue Wang, and Xinge Wang, "Application of Blockchain Technology in Online Education," *International Journal of Emerging Technologies in Learning*, vol. 13, no. 10, pp. 252-259, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[23] Masumi Hori et al., "Learning System based on Decentralized Learning Model Using Blockchain and SNS," *Proceedings of the 10th International Conference on Computer Supported Education*, vol. 1, pp. 183-190, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[24] Stéphane Silva, Francisco Pires, and Jorge Bernardino, "Editorial Platform in Blockchain for Application in Higher Education," *Proceedings of the 16th International Joint Conference on e-Business and Telecommunications*, vol. 1, pp. 221-227, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[25] Bin Duan, Ying Zhong, and Dayu Liu, "Education Application of Blockchain Technology: Learning Outcome and Meta-Diploma," *2017 IEEE 23rd International Conference on Parallel and Distributed Systems (ICPADS)*, Shenzhen, China, pp. 814-817, 2018. [CrossRef] [Google Scholar] [Publisher Link]