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TrCert: Transfer Certificate Generation System during Student Transfer using Blockchain Technology

[1] Sri Santhoshi Devi ARIGELA, [1] Persis VOOLA,
[2] Chirag Arunbhai JANI, [3] Veera Nagendra Kumar SUNKARA,
[4] Sri SatyaDevi ARIGELA, [5] Venu Madhav KANAMATAREDDY

[1] Department of Computer Science and Engineering, Adikavi Nannaya University, A.P., India
[2] Department of Information Technology, CGPIT, Uka Tarsadia University, Bardoli, India
[3] Security Delivery Associate Manager, Accenture, Bangalore, India
[4] Manager and Scrum Master, Optum Global Services India Pvt Ltd, Hyderabad, India
[5] Solutions Architect – AI and Agentic Systems, Amazon Web Services (AWS), San Francisco, USA
[*] E-mail: srisanthoshidevi@gmail.com, persisvoola.cse@aknu.edu.in, chiragjani5901@gmail.com, svnkumars@gmail.com, srisdarigela@gmail.com, kvenum@amazon.com

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Abstract: In this article, we propose an application using blockchain technology called TrCert which is used to generate, store, and share the transfer certificate to help educational institutions to eliminate fake candidates and provide security and efficiency. The certificate is generated by the University when a student applies for transfer from one college to another college. It allows the transfer of authentic users from one educational institution to another educational institution and provides the information in a secure and tamper-resistant manner. TrCert is developed by integrating Ethereum smart contracts with IPFS (InterPlanetary File System). IPFS stores the certificates in a decentralized file system.

Keywords: Blockchain, Academic certificate validation, Smart contracts, Solidity, IPFS.

1. Introduction

Many blockchain technology applications have been developed for educational purposes. This technology will change the educational sector in a variety of ways including management of digital educational certificates, fees, education-industry cooperative system, academic grades, student data privacy, examination review, online quiz, copyright management, credit transfer, reputation and reward and system for analyzing student capability, lifelong learning support, academic record and rewards, meta-diploma, skill competition, online education, learning outcomes, university grades [1, 2].

In this article, we are mainly focusing on the generation of transfer certificates for a student. The perceived challenges with the current process for transferring from one college to another can be:

- Very time-consuming;
- Manual and physical verification process of documents;
- The authenticity and provenance of the documents are difficult to determine;
- Longer delays due to miscommunication;
- Possibility to modify the information in the documents.

Blockchain can be leveraged to develop unique digital assets that provide reliability to student information. This would make educational institutions know about the student information in a simple way and save the cost and time involved in that procedure. TrCert, the system we propose in this article, uses the

concept of blockchain and smart contracts to generate the transfer certificate. TrCert is implemented by using the Ethereum public blockchain network and the Solidity language for the execution of the smart contracts. The generated transfer certificate will be encrypted and stored on the IPFS storage system.

The most important roles involved in this transfer certificate system are the university, the college, and the students. Different nodes on the network can generate and validate the credentials for the users participating in the network. The current college is responsible for the generation of transfer certificates, which contain details like student name, name of the degree(course), current college name, the college name to which transfer is applied, and serial number assigned by the system (unique identification for the student).

1.1. Article Motivation

Nowadays, the number of students applying for transfer from one college to another is increasing due to several reasons. It is difficult for a college/university to know the correct information about students, whether the student studied in the mentioned educational institution, and other information.

Edgecoin, Sony Global Education, Tutellus, TeachMePlease (TMP), SuccessLife, Blockcerts, GradBase, Echolink, OriginStamp are some of the applications available in the education field. These applications are used to store academic certificates (Edgecoin), secure and distribute the student record using blockchain(Sony Global Education), decrease the cost of education for college students (Tutellus), provide group sessions or individual classes to students(TeachMePlease), organize the workshops and seminars(SuccessLife), to encrypt the student data and issue e-certificate(Blockcerts), verify the educational records(GradBase), stores the data(Echolink), provides security to digital data (Origin-Stamp). It is found that neither the applications developed nor the research had a mention of the generation of a transfer certificate system for students [3].

National Education Policy 2020(NEP 2020) provides flexibility to the students through a multiple entry and multiple exit policy where a student can study in an educational institution of his/her choice, abiding by the prevalent rules, which facilitates the transfer from one educational institution to another after every year of study. However, all the state universities have to adopt the spirit of NEP 2020, which is going to revolutionize the education system in the state and the country as a whole [4].

1.2. Related Work

Educhain is an education information management system that effectively deals with increased security of alteration, storing, and sharing of certificates and grades across the globe. Educhain emerged with the objective of introducing blockchain technology to corporations, academic institutions, and government at all levels. The key benefit of Educhain is the utilization of a heterogeneous blockchain system, which provides a reliable and dynamic approach to storing and validating various types of information. Each node in the system possesses its own database. Data is duplicated across all nodes, and redundancy is the main problem in this system. This must be eradicated with improved security measures [5].

Bcert is a distributed and decentralized system implemented by using blockchain technology, which is utilized to generate, store, issue, view, verifying academic certificates. They are considered as digital records that are listed on blockchain technology, cryptographically signed, tamper-resistant, and shareable. It uses Ethereum smart contracts for validation and distribution of the certificates, and IPFS is used to store them. Bcert is an open-source platform. Bcert reduces the cost of transactions and smart contract implementation.

2. Overview of Blockchain

2.1. Blockchain Technology

The blockchain is known as the underlying technology of Bitcoin and other cryptocurrencies. It is also described as a shared, distributed, and digital ledger that gets continuously updated with all the transaction information. It can be considered an economic and technological revolution. The blockchain is a set of cryptographic techniques and protocols implemented by a network of nodes that collectively work together to complete the secure and safe recording of data inside a distributed database that contains encrypted blocks encapsulating the data.

The evolution of blockchain technology from 1.0 through 4.0 is an improvement over the previous versions, and the applications at each level addressed different aspects as follows [6].

Blockchain 1.0 is about the currency, and the deployment of cryptocurrencies in applications related to cash, such as currency transfer, remittance, and digital payment systems.

Blockchain 2.0 is related to contracts, the entire slate of market, economic, and financial applications using the blockchain that are greater in scope than simple cash transactions. They are mortgages, titles, stocks, futures, loans, smart property, bonds, and smart contracts.

Blockchain 3.0 is concerned with blockchain applications beyond markets, currency, and finance, particularly in the areas of art, culture, literacy, science, health, and government.

Blockchain 4.0 is related to blockchain applications with AI. Seele and Unibright are the platforms that introduced blockchain 4.0 applications [7].

2.2. Features of Blockchain

a) Decentralization: The distributed environment in blockchain technology utilizes the standard protocol to ensure that every participating node receives every transaction and implements predefined rules for organizing transactions into blocks. Blockchain technology is developed for distributing and transmitting data across various networks.

b) Distributed: It is one of the key advantages of blockchain since there is no need for a centralized authority, as each node keeps a record of all transaction data. It prevents the single point of failure problem. It does not have a single authority, and there are no service fees. Data consistency is maintained by using consensus algorithms [8].

c) Security: Blockchain network provides security by implementing the one-way hash function, a mathematical operation that converts a variable-length input text into a fixed-length output. It is impossible to determine the input from the output.

d) Efficiency: The data in the blockchain network follows pre-determined processes. As a result, blockchain technology can increase efficiency and decrease the cost of labor. In blockchain 1.0, the automation of the settlement of digital currency is accomplished using distributed ledger technology. Blockchain technology could accelerate the clearing and settlement of specific financial transactions by reducing the number of intermediaries involved and speeding up the reconciliation process, which makes it more efficient [9].

2.3. Smart Contracts

Over the last decade, blockchain has developed as a prominent academic pursuit. A smart contract is a computer program that has self-executing, tamper-resistant, and self-verifying properties. By integrating smart contracts with blockchain technology, can complete a transaction at a lower cost and with a higher level of security in real-time [10].

Implementation of smart contracts can be done using the Solidity language, which is a high-level and object-oriented language. It is also known as the most popular programming language for writing smart contracts, and it uses the Ethereum platform for execution [11].

Smart contracts also enhance the capabilities of blockchain-based systems by implementing all of the rules and regulations associated with a particular logic or business process. Decentralized apps (DApps) can be developed by implementing smart contracts using a blockchain platform, with the backend consisting of a P2P decentralized network of nodes [12].

Since smart contracts are implemented and secured by blockchain technology, they provide benefits of improving the efficiency of corporate processes, help in saving administration and service costs, and lower transaction risk.

3. Proposed Methodology

3.1. System Architecture

The proposed architecture with blockchain as backbone and universities, colleges, and students as users in different roles, as shown in Fig. 1. We are digitalizing the process of transfer at the university level using blockchain technology. Universities and their affiliated colleges are registered in this system. All the students of universities/colleges can register using the system. All the data related to universities, colleges, and students is stored securely in the blockchain after registration.

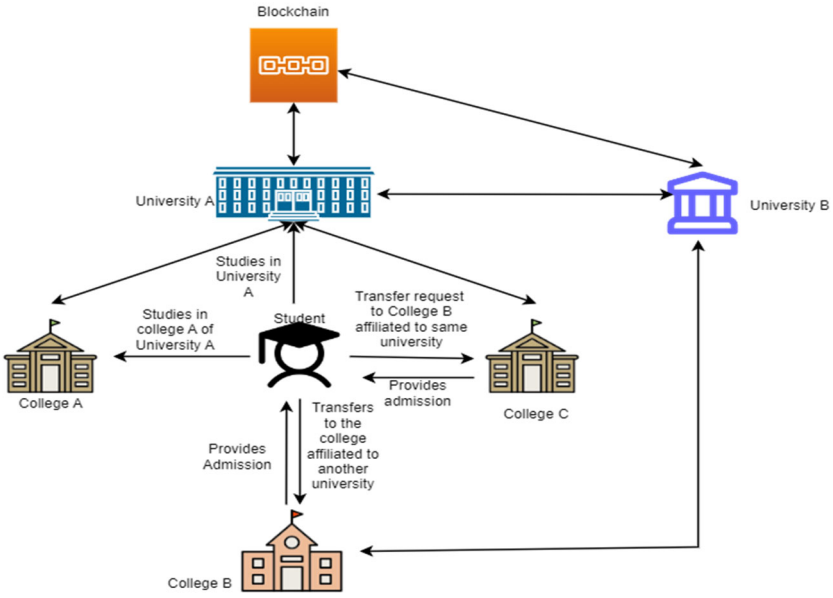

Fig. 1. Block diagram of the proposed Architecture for the Student Transfer Certificate System (TrCert).

The system is secured by providing the Metamask authentication mechanism. Authorization will be based on the roles of the users. Users will be authorized based on a role-based access control (RBAC) system. Data will be stored in the IPFS storage system. Once the student initiates the transfer, the system will send data to the required parties. The parties process the transfer from their end. Once the process is completed, the system will generate the transfer certificate (TrCert). The generated certificate using blockchain technology is tamper-resistant.

We have considered the following cases of student transfer:

- From one college to another college, both of them are affiliated with the same university;
- From one college to another college, both are affiliated with different universities;
- From one university to another university.

If the student is transferring from one college to another college affiliated with the same university, he/she has to submit the following documents:

- Marks list;
- Transfer certificate;
- No objection certificate.

In case of student transfers to a college that is affiliated with a different university, he/she has to submit the Migration certificate along with the above-mentioned documents.

A college can be a:

- Government College;
- Private college;
- Autonomous college;
- Non Autonomous college.

Some of the reasons students transfer from one educational institution to another include:

- Medical grounds;
- Parents transfer to other places;
- Closure of the current studying college;
- Spouse working in another place in case of married students.

The block representation of the proposed TrCert Architecture for Student Transfer Certificates is shown in Fig. 1.

3.2. Implementation

The proposed architecture for the student transfer certificate system in an educational institution consists of various stakeholders. There are three types of users considered for the proposed architecture. They are student, college, and university. The mentioned users play specific roles, which are presented below.

Student: The student is enabled to register for the application by sending sign-up requests. After registration, the student can access the application. The student selects the college to which he/she wants to transfer.

University: The university is enabled to see the initiated transfers from students and can check the details of students. It is also able to see the available seats in the corresponding colleges. If seats are available, it communicates with the college/university about the student's transfer.

College: Once a student sends the registration request, the college receives the information of the student. Checks the student information and provides access to the application. College can see the student-initiated transfer requests and corresponding seat availability in both colleges.

The developed blockchain technology application is provisioned to deal with the following cases.

Case1: Transfer from one college to another college within the same university

Once the student initiates the transfer, the transfer request goes to the university. The university reviews the transfer request means it will approve or reject the request. After the review process, the application moves to the corresponding college. The corresponding college reviews the request, checks the documents of the student, the availability of the seats, and course checking. If the seats are available, the college will accept the application. Once the corresponding college accepts the student transfer request, then the current college will check the application and generate the transfer certificate. The generated certificate will be given to the corresponding college and student.

Case2: Transfer from one college to another college both are affiliated with different universities

Once the student initiates the transfer, the transfer request goes to the new university. New University reviews the transfer request means it will approve or reject the request. After the review process, the application moves to the college. The corresponding college reviews the request, checks the documents of the student, the availability of the seats, and the course. If the seats are available, the college will accept the application. Once the corresponding college accepts the student transfer request, the current college will check the application and generate the transfer certificate.

The implementation set up for the proposed TrCert framework is illustrated in Fig. 2.

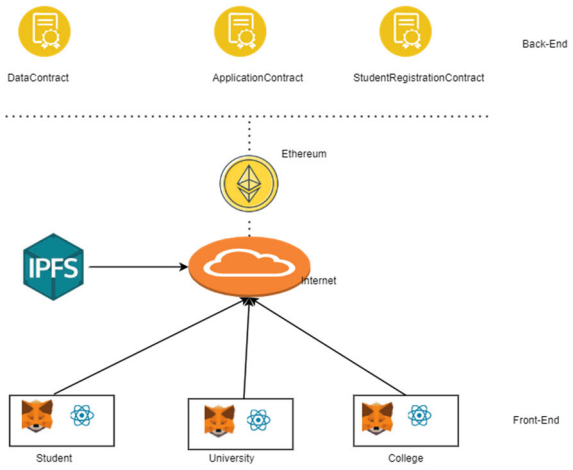

Fig. 2. Implementation set up for TrCert.

3.3. Design of Smart Contracts

Based on the proposed architecture, three smart contracts are developed, which are discussed below.

DataContract: DataContract is developed to store on-chain data about universities, colleges, and students. This contract can also be used to retrieve the information of all the stakeholders. It contains the functionsaddStudent(),addCollege(), addUniversity(), getUniversityInfo(),getCollegeInfo(),getCourseInfo(), mgetStudentInfo().

Fig. 3 illustrates the implementation snippet of the data contract.

StudentRegistrationContract: The purpose of this contract is to provide login and Logout for all users. It also handles sign-up requests by students and approval or rejection of sign-up requests by the corresponding colleges. It contains the functions signup(), approve(), auth(), getStudentList().

Fig. 4 presents the code snippet of StudentRegistration Contract.

ApplicationContract: This contract is used to implement the functionalities like the creation of transfer requests, university reviews and forwarding the request to the corresponding colleges, and approvals by colleges to the transfer requests. It contains the functions initiateTransfer(), transferApplcationToCollege(), approveOrRejectApplication().

Fig. 5 depicts the solidity code snippet for the Application contract.

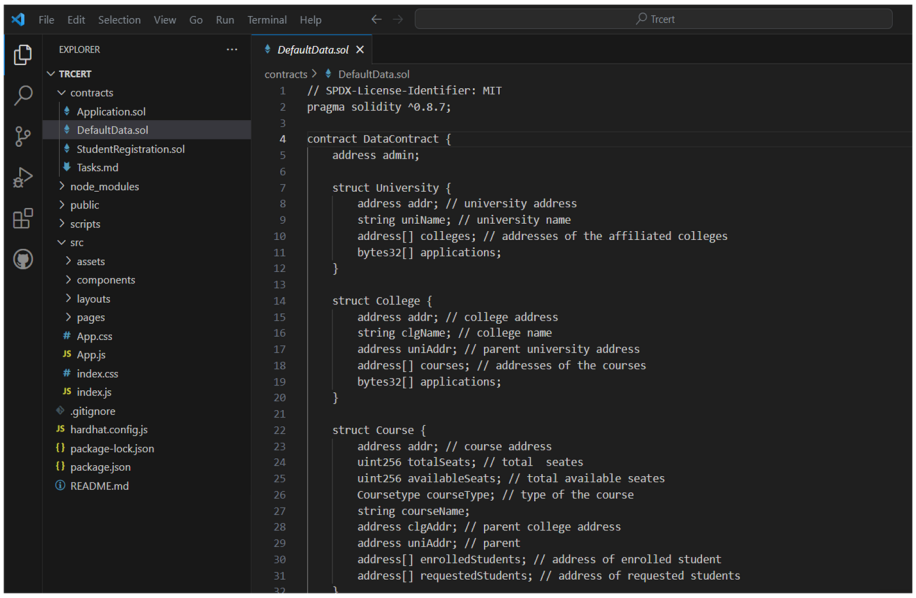

Fig. 3. Code Snippet of Data contract.

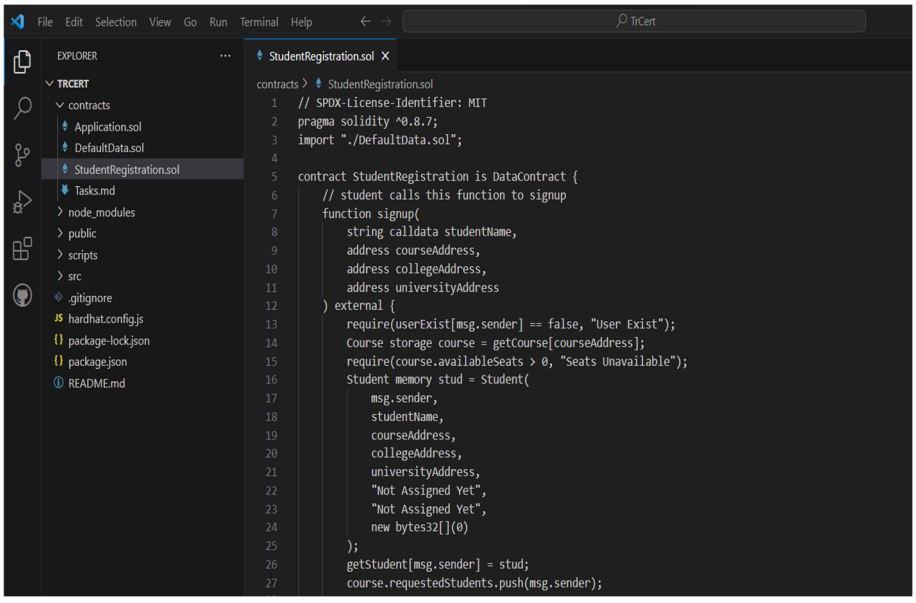

Fig. 4. Code snippet of StudentRegistration contract.

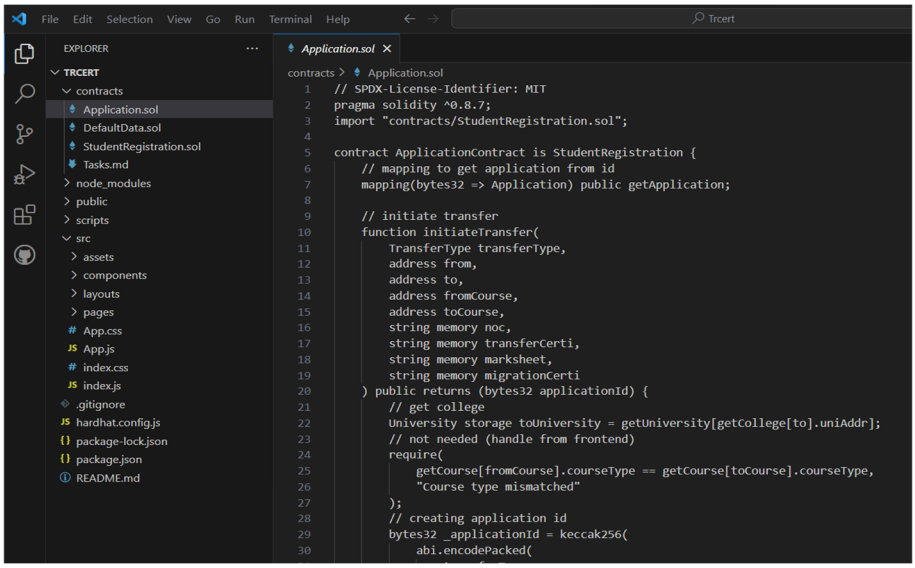

Fig. 5. Code snippet of Application contract.

3.4. Software Used

a) Programming Language: Solidity: Solidity is a high-level and object-oriented language designed for developing smart contracts. Smart contracts are programs that influence the functionality of accounts within the Ethereum state. Solidity is mainly designed to work with the Ethereum Virtual Machine and is influenced by JavaScript, C++, and Python. Solidity is a statically typed language and provides support for libraries, complex user-defined types, inheritance, and other features [13].

b) Remix IDE: Remix-IDE is available as a desktop application or web application and as a Visual Studio Code (VSCode) extension. It is a tool for developing smart contracts. It supports a rapid development cycle and includes a rich set of plugins with intuitive GUIs. The Remix project contains Remix Plugin Engine and Remix Libraries, which are low-level tools for general use [14].

c) Metamask: Metamask provides the easiest and most secure mechanism to connect to the applications built on blockchain. It is accessible as an extension of the browser. It allows users to easily access decentralized web applications. Users can connect with the Ethereum blockchain and avail of the features of Metamask, like user account creation, accessing the data, and information to share or not to share (keeping it private). Metamask provides the token wallet, secure login, token exchange, and key vault to users to manage digital assets [15].

d) React: React is a community-supported, open-source front-end framework, and it is developed by Meta. A React app mainly contains components. A component can be a part of a user interface (UI) possessing its unique logic and appearance. The size of the component can vary from a small button to as large as an entire page [16].

e) IPFS: IPFS stands for Interplanetary File System. It is used to store the blockchain application off-chain data and provide the data to users upon request. When a file is uploaded to IPFS, divides the file into smaller parts, and applies cryptographic hash functions after that provide a unique fingerprint referred to as Content Identifier (CID). CID functions as a permanent record of the stored file during its existence [17].

f) Ethereum: Ethereum is an open source blockchain network, a decentralized software development platform with the cryptocurrency ether (ETH). Ethereum serves as a safe, secure, and worldwide platform for an emerging generation of revolutionary applications. Since it is open, anyone can access the Ethereum network. Need not have any permission. It is developed and continuously maintained by thousands of individuals, groups, and users worldwide and has no owner. It is used to run smart contracts and implement decentralized applications (DApps). Ethereum is commonly used to develop blockchain applications due to its robust security, smart contract utilization, large developer ecosystem, and strong support for decentralized applications [18].

g) Hardhat: The environment for creating Ethereum software is called Hardhat. It consists of various components to edit, compile, and deploy the dApps and smart contracts. All of them work together to form a complete development environment. The components are:

- Hardhat Runner;
- Hardhat Network;
- Hardhat for Visual Studio Code;
- Hardhat Chai Matchers;
- Hardhat Network Helpers [19].

It is a local Ethereum network designed for developing smart contracts. It is one of the best tools for solidity debugging. When transactions fail, Solidity stack traces, console.log, and explicit error messages are generated. It is easy to catch errors without executing code by moving to a typed

language. Hardhat offers complete language. Hardhat offers complete native support for TypeScript.

h) ethers.js: It is a JavaScript library. For connecting to the Ethereum Blockchain and its ecosystem, the ether.js library provides a complete and compact library. It was initially created to use with ethers.io, and it has become a more general-purpose library. ethers.js also:

- provides support for JSON wallets;
- manages the private keys of clients;
- uses Metamask for connecting to Ethereum nodes [20].

4. Results

Three smart contracts are developed and deployed on Ethereum. The miners involved in the Ethereum network need to be economically rewarded in terms of incentives. As a result, smart contracts of blockchain incur operating charges. The operating charges of three smart contracts have been calculated by using the Remix tool. Table 1 shows the cost (in terms of Gwei, Ether, and USD), gas used, and gas limit kept during the calculation. Table 2 is about comparative study of Educhain, Bcert and TrCert.

Table 1. Comparison of the cost of smart contracts.

Contract Name	Cost (Gwei)	Cost (Ether)	Cost (USD)	Gas used	Gas Limit
DataContract	10271421	0.0102714	16.80	3043384	3043384
StudentRegistration Contract	16169155	0.0161691	26.45	4917901	4917901
ApplicationContract	13148244	0.0131482	21.51	4081245	4081245

Table 2. Comparative study of three platforms.

Title of the Research Source	Educhain: A blockchain-based education data management system	Bcert: a decentralized academic certificate system distribution using blockchain technology	TrCert: Transfer Certificate Generation System during Student Transfer using Blockchain Technology
Authors	Y. Liu, K. Li, Z. Huang, B. Li, G. Wang, W. Cai	E. Leka, B. Selimi	Sri Santhoshi Devi Arigela, Persis Voola, Chirag Arunbhai Jani, Veera Nagendra Kumar Sunkara, Sri Satya Devi Arigela, Venu Madhav Kanamatareddy
Publication Year	2020	2020	
Publication	CCF China Blockchain Conference (Springer Proceedings)	International Journal on Information Technologies & Security	
Primary Aim	Develop a blockchain-based system to deal with complex educational data	Develop a decentralized blockchain-based academic certificate issuance and verification system	Develop a decentralized blockchain-based academic certificate issuance and verification system & Develop a decentralized application used to generate, store and share the transfer certificate
Type of Blockchain	A heterogeneous blockchain contains properties of both private and consortium blockchain	Public blockchain based certificate verification system	Public blockchain based transfer certificate generation system
Security Aspects	Immutability, Traceability and Data integrity	Decentralized Verification, Tamper-proof certificates	Decentralized, Distributed and provides transfer certificate in secure and Tamper resistant manner
Stakeholders involved	Administrators, Students and Educational institutions	Employers, Students and Universities	Students, Universities and Colleges
Issues Identified	Lack of data transparency, trust and centralized storage risks	Manual verification delays, fraudulent certificates	Time consuming, Certificates forgery, Challenging task of student transfers
Implementation Detail	Architecture and system model are discussed	Framework design and work flow for certificate verification	A simple and useful architecture is proposed and implemented

5. Future Work

The present system in this article deals with transfer certificate generation (TrCert) on approval of the both University and the college. However, in practice, academic equivalence also has to be verified i.e., whether the courses the students have already studied in the current college do satisfy the programme requirements of the college to which the student is seeking transfer. An academic equivalence certificate has to be incorporated to satisfy the existing guidelines of the university. We have implemented blockchain technology in the College Development Council (CDC) section, which deals with student transfers.

a) Cases that are not covered in this research: This research does not consider cases that break of study and readmission. We have mainly considered the transferred student data of graduation. Research on transfers of students studying PG and other areas needs to be covered. The implementation of the proposed system covered two cases: when a student transfers from one college to another college, both are affiliated with the same university, and from one college to another college, both are affiliated with different universities. It didn't cover the other case, student transfers from one university to another university.

b) Blockchain in other sections of the University: The usage of blockchain technologies needs to be expanded in the areas of the university, like the Administration, Examination section, Research and Development, and so on.

c) Customization for accommodation of Universities: We have developed the TrCert application based on blockchain technology, which is a generic application. Universities/Colleges that wish to use this application for the generation of transfer certificates can use this application by incorporating necessary changes like the names of colleges, Universities, courses, and students based on their requirements.

d) Need for Blockchain Technology for implementation of NEP 2020: NEP 2020 is the first education policy of the 21st century that plans to deal with the many rising developmental imperatives of our country. This Policy recommends the amendment and revamping of all aspects of the education structure, including its regulation and governance.

To accomplish the goals of the National Education Policy2020, the National Credit Framework (NCrF), a national credit accumulation and transfer system, has been developed. It will combine general and vocational education while assuring candidate mobility between the two systems. Implementing NCrF will improve the international exchange of students and faculty with foreign universities and enable equivalence of courses and qualifications. It will also provide guidelines for credit transfer. The credit transfer mechanism will also permit a student to join, exit and re-join the educational ecosystem both general and vocational at any point of time [21].

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The proposed equivalence under this national credit framework enables learners with either a general education background or a background in vocational education and training/skilling can acquire the necessary credits to re-enter the mainstream education system. The Multiple Entry Multiple Exit (ME-ME) can be done when the entire education ecosystem especially when it comes to the case of higher education is partitioned into yearly independent modules. To support vertical and horizontal mobility between education and skilling, it is essential to develop a unified credit system for the integration of vocational education and training/skilling into school and higher education to comply with the National Education Policy 2020. To do this, NEP 2020 also suggests creating an "Academic Bank of Credit" (ABC) that could digitally maintain the academic credits obtained from accredited universities so that degrees could be granted, taking into account credits obtained.

Therefore, to enable the effective implementation of NEP 2020, an immutable, transparent accumulation, storage, transfer, and redemption of Credits, a more robust framework is required. Blockchain technology comes into the picture in order to achieve the features of the mentioned framework. The researchers can use smart contracts, permissioned

and permissionless blockchain configurations for further implementation.

6. Supplementary Data

The research work presented in this manuscript originated as part of the author's Ph.D. research and is documented in Chapter 5 of the thesis available in Shodhganga at Shodhganga Thesis Repository [22]. The related conference paper titled "Integration of QR Code with the Transfer Certificate: A Novel Application of Blockchain Technology," included as Chapter 6 of the thesis, represents a subsequent extension focusing specifically on QR-code integration within the broader TrCert framework [23].

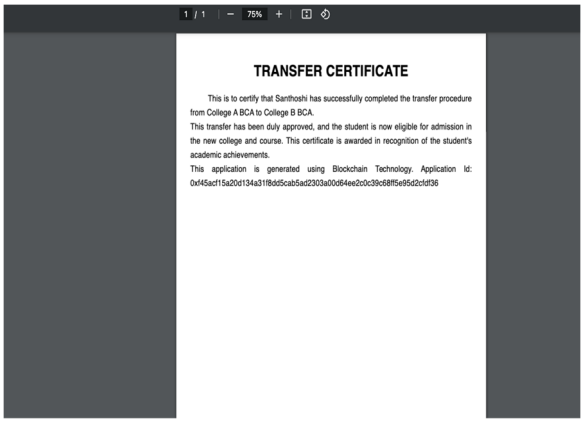

Fig. 6. Transfer certificate generated by College A.

Additionally, implementation screenshots and supporting materials have been maintained through a GitHub repository as part of the research documentation and reproducibility efforts [24].

7. Conclusion

Blockchain technology is used to address the challenging task of student transfers in colleges/Universities. In this research, a simple and useful architecture is proposed that contains various users, their roles, and the core functionalities of the architecture. Three smart contracts are developed and deployed as the key components of the DApp. The Ethereum blockchain is implemented for the testing and validation of DApp. The different costs of developed smart contracts are calculated and shown in tabular form. The Trcert makes the transfer certificate immutable and legitimate.

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