



Education Certification and Verified Documents Sharing System by Blockchain

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Abstract: The emergence of new and improved technological advances created severe problems in the security state of the educational certification system. Throughout this paper, a proposal has been made to improve security. Here, Blockchain technology has been introduced as reliable secure storage for the educational certification system, providing an additional facility to the users. That is the validation and authentication of the student's academic records. Moreover, for security purposes, Blockchain technology can replace the traditional academic certification system and contribute to a new model for sharing student information. After completion of data inclusion and hashing, the blocks will be inserted into the Blockchain network. This proposed model enhances document security and fraud reduction and additionally reduces a significant amount of authentication time almost up to double the current speed. With this system, we will get a certification process in which all data will be digitalized and secured in an unbreakable database with proper authentication and with a noticeable amount of time efficiency.

Keywords: Blockchain, Security, Educational systems, SHA256, Hashing.

1. Introduction

Blockchain technology is a distributed ledger-based data recording process [1]. It gives us the privilege of safety and security to users, ensuring no change in the data recording process. This technology was first introduced to us as a mathematics-based foundation for the digital peer-to-peer cash Bitcoin by 'Satoshi Nakamoto' in 2008. The name Blockchain consists of the words block and chain. These two words indicate the functionality of Blockchain technology in that transactions are at first grouped in blocks just like a data package. These packages are chained sequentially to each other to connect each new block with its previous block. This indicates that a blockchain represents a complete ledger of that transaction with all its history [2].

The decentralization of Blockchain provides the system freedom from the control of any specific individual. This also means that no central authority

is needed for this network to run smoothly, which provides more security and transparency. Besides this, as the complete transactional history is available with each recent block, it provides a guarantee to fully rely on it. After all of these security facilities, Blockchain also includes the hashing process after storing the transactional values as well as the timestamp in the block. A hash value is a string that contains a mixture of letters and numbers with fixed size and length [3]. This hash is mainly created by a cryptographic hashing function currently using the SHA256 function and stored in the previous block of the network along with a random number called the nonce. This nonce is used to validate and inspect the hash value and the entire Blockchain [4].

This lengthy procedure might be a hassle from one angle, but it becomes difficult for an unexpected user to change the values because a single character change in the transaction results in a new hash value that does not match the stored hash value in the preceding block and, as a result, it creates a problem

[2]. Furthermore, the process of better attack resistance and fault tolerance provided as a result of its distributed nature is much more appreciated by its users.

In this proposal, the Blockchain is to be implemented in the education system in a combined way of a private and public Blockchain to bring out the most effective result. With the aim of providing transparency, certificate authentication, and security, the idea is brought to light. Some part of the proposed algorithm is to be applied with the private Blockchain method for restricted permission behavior, and the other part is implemented with the public Blockchain method using the concept of consortium Blockchain. Here, sharing information with other institutions does not require a specific way, whenever any university or institute under Blockchain adds a block to Blockchain it is automatically shared with other members due to decentralization [5]. There will be multiple types of stakeholders, such as universities, employers, and students. As Blockchain is a platform where a lot of institutions or companies or just a lot of information can be saved in the system without being manipulated by any other third party, it can be considered the best platform for keeping all the information of educational institutions [6, 7, 8]. As educational information is very sensitive and is manipulated most, it is important to keep them safe and secure. Any kind of safety violation can cause a lot of problems for educational institutions and students. Certificate manipulation is one of the reasons behind unemployment, so keeping educational information safe and verified is another priority. Therefore, because of the hashing technology, it is sort of impossible to break the chain by any intruder. But by any chance, if any imposter succeeds in manipulating 50% of blocks of any connected member and the block's hash does not match other members, the entire system will shut down until it is fixed. This process is called a 51% attack. So, Blockchain is perfect for handling all the issues in this sector [9, 10].

For example, for the first reason, it is normally maintained by a central authority that can easily access the database and update the necessary information. But from a security point of view, any highly skilled hacker can easily access using the vulnerable security protocol method and copy or change any information they require; this, on one hand, lacks personal information security, and on the other hand, it can be considered as an institutional security issue as well.

Moreover, the inclusion of a wedge increases the budget for maintaining the database [8, 11]. For an educational institution, sharing and authentication of

student information with other institutions and employers might result in a lengthy process, and it might consume a large amount of time. Therefore, from these points, we can conclude that a database is not an ideal option to store and maintain student information for educational institutions.

In the world of technology, the education sector has improved a lot, but basic manual work is needed to store or publish records. To evaluate and establish a fair education with proper security, this is high time we should adopt a more efficient algorithm. Moreover, there are other issues like data manipulation, data loss, server for huge data collection, and, more importantly, the verification of academic records.

Another thing is that when a student applies for a job, employers also face the need of verifying the information, and they must invest a lot of time, human resources, and money. To solve this issue, if a system can be made to ease the process of data verification and the employers can be able to see the academic records alongside the other activities, would be the best solution.

The main aims and objectives of this research are:

- Keeping confidential documents of students and organizations secure from manipulation.
- Uniting different universities together and making a way to connect and collaborate with different companies and organizations.
- Enriching and increasing opportunities for national and international employment.

One of the research problems in this work is to develop a better graphical framework that provides an extra level of security. So, our proposed graphical framework model, which is built in the PHP language is going to be used to handle the server and database to provide an extra level of security in the system before passing the data in the block. In addition, we use SHA256 hashing for encrypting the data and then inserting the data into the Blockchain model.

In the next sections, the whole paper is organized in a systemic structure. The related work and the background study are described in section 2. Moreover, section 3 is designed with system architectures and methodologies. In addition, section 4 shows the effectiveness and efficiency of the proposed model. Finally, section 5 provides concluding remarks.

2. Related work

The basic private Blockchain technology is one of the technologies that have been proposed to create a system that can combine two separate

Blockchains and connect them internally so that information of the respective Blockchain can be shareable among each other containing valid educational information. One of the systems is issued for the ‘issuer’ and another one is for ‘authorized personals’. For further verification systems, a digital signature is used and it also increases security by the use of the private key and public key in this process.

Throughout the whole procedural description, the outlook on how using private Blockchain for a particular institute and its verification process can be secured by using two Blockchain systems depending on the user, also interconnecting the system to work harmoniously, can be understood. Moreover, this involvement of third parties can be reduced and can increase the performance of the system. Additionally, numerous educational issues such as keeping a record of everything can be easily solved based on the smart contract provided to us using Blockchain technology.

Among the good perspectives of the paper, we can identify some of the flaws as well, such as, using two separate private Blockchains in one institute may complicate the system and also wastage of space. Furthermore, having students as issuers can be harmful to the institution as they become part of the administration of the system. Furthermore, there is no vast explanation of how the system may conduct the work. Throughout the whole proposal, here is for a trivial institution. But as the Blockchain is a very secure system and can store data along with verification, it is pretty obvious to use it for a larger platform. And in a larger platform only using a private Blockchain is not sufficient. Education is in general a very important matter to look at and its certification and verification are more important to ensure. Therefore, it should be observed thoroughly and come to a more explicit design of the education system [12].

Blockchain has been used in different technological areas. But the higher education system is the one that needs it now. As different levels of administration work to process transcripts, Blockchain is a way to be fitted as a digital solution. The whole proposed process has been performed using only Blockchain technology.

Throughout, we have identified some good sides of the whole proposal. First of all, the transcripts can be stored in the higher security system generated by Blockchain technology, and the records can be easily manipulated or edited by using the NoSQL database. This proposal has aimed at the ambulant education system so that the learners of any institute do not hesitate to change educational institutes due to stress. In addition, they will be able

to take advantage of technology. We have also identified some flaws in the whole system. Such as the proposal includes a model that can be edited using a NoSQL database. The main purpose of implementing Blockchain-based technology in the system is to make the education system tamper-proof, and this proposal may lead to disadvantages to some extent. But this model can be modified and updated in some procedures. As currently the system is being applied, and the further result will be published later on. Therefore, the effectiveness and comparison with other technologies could not be found [13].

A certificate is considered an essential part of one’s career. The Blockchain is a permanent way of storing data. But these data are verified at first, and when it is stored, it is permanently stored. Throughout this paper, we will be notified by first issuing a second validation and finally safely sharing certificates with the implementation of certain perspectives as well. An interplanetary file system has been proposed to be implemented in the system for the storage of profile information. Moreover, the BSCW (basic support for cooperative work) document management system is considered to be used for the storage and validation of the certificates and SHA256 for the encoding process.

The system can be advanced through some inclusions. Such a system can be introduced with a process so that if the private key is forgotten or compromised, it can be accessed in any other way or retrieved the private key at any cost. Second, if the certifier could issue a pre-signed transaction to an alternative authority, it might refund the certifying authority and then submit the block in the network [14]. EduCTX is a platform for a global higher education credit using Blockchain. It is mentioned that it is a more technologically advanced and transparent platform for higher educational systems. The system is created based on breaking language barriers and connecting globally. This proposed model named ‘EduCTX’ has proposed a higher education credit platform based on Blockchain. It provides users with a decentralized and trusted educational credit and grading system.

First, in the European credit transfer and accumulation system (ECTS), multiple technologies have been implemented to achieve this proposed model. Second, a prototype based on the open source Ark Blockchain platform, and finally a globally distributed peer-to-peer network [15]. The paper has been offered as a globally integrated method for students along with higher education institutions (HEIs), and prospective stakeholders, for example, organizations, corporations, and institutions. All

students will have their accomplished education and course history in transparent storage. Furthermore, universities will have these accessible data and the latest ones, based on the student's educational base of the student. On the other hand, dissimilar organizations such as other universities and employers as potential users can get the information validated whenever they need to.

Despite having such advantages, the system is complex. If a student somehow forgets the private key and fails to prove the authenticity of his EduCTX Blockchain with his/her ECTX tokens, the student will have to visit his home education institute himself and a new Blockchain address will be issued [15].

3. Methodology

To solve all the insecurities and bring more opportunities, we propose a Blockchain-based education system. Our proposed system will be introduced focused on the authentication of academic records and combine the educational institutes to create a larger storage system. Lastly, other potential stakeholders such as employers and companies will also be added to the system so that they can easily recruit employees without worrying about the original grade report. We are using blockchain for our proposed model. Even though the concept of implanting Blockchain is nothing new to the world, the actual implementation is purely limited. Eventually in Bangladesh Blockchain is yet to be introduced into the education system.

The Blockchain is a distributed ledger system. What makes it more secure is that everyone connected to the system has a copy of the ledger. After adding a new block to the system, all the nodes connected to the system receive a copy of the block, which makes the network decentralized. Therefore, if anyone wants to manipulate the information stored on the system will have to manipulate at least 51% of the user's information [16]. That is nearly impossible in real life. The computational power required for this process is exceptionally high in Blockchain because of the hash function.

The digital signature is added to each transaction to ensure trust and transparency. Each node connected to the system holds a primary key and a public key on its own. As it is named, the public key is open to everyone and anyone can see the public key of another person, but the private key is only known by the owner. If someone wants to share a piece of information with another, he has to make a transaction signed with his private key. Along with the sender's private key and the message inside the

transaction decides on the digital signature is decided, so the data is encrypted. The sender's public key is used to verify that the message was originally sent from the sender. Without knowing the secret or private key, the 256-bit signature is nearly impossible to find. Thus, other nodes cannot forge any information using the name of one node or authentication. Thus, another characteristic of Blockchain is that the information is encrypted with a digital signature for authentication purposes and safe from alteration from the outside.

There are three types of Blockchain: public Blockchain, private Blockchain, and consortium Blockchain. All three types of Blockchain are different from each other based on the level of permission. A public Blockchain is completely decentralized and anyone in this world can be a user of the Blockchain system. He will be able to send, store, and receive information through the network only by installing the required software. The private Blockchain is more of a restricted kind. A consortium Blockchain is a hybrid network that combines private and public Blockchain behaviors. In this technology, some potential parties are predetermined. Instead of being owned by an organization or fully decentralized, the predetermined parties can take control of the authentication process. fully controlled We are using consortium Blockchain in our system to make it feasible in some cases but also make sure it is strictly private in other cases. Student records are the most sensitive information for educational institutes. When uploading and storing the information to the network, the information must be verified by an authorized person. At the same time, the connected nodes should be able to access the information for other needs. So, the universities connected to the network are part of the private Blockchain and the companies connected to the system are part of the public Blockchain.

The model we propose is to combine all the universities and companies altogether. There will be a large network of different stakeholders. Here, student information and certificate will be verified, and the companies will be able to recruit easily. The verification process helps students with a declining long and slow procedure to apply and collect their certificates from universities. They will be able to transfer their earned credit from one university to another very easily. Not only that, but the companies recruiting students from a particular university will be rewarded with some points, and the students recruited from a university will bring reward points to the university. In this way, the picture will be clearer to see from which university

Algorithm 1 SHA-256 Algorithm

Step 1:

- Convert the input into binary.
- Append a single '1' and pad the input with '0's until the input length is a multiple of 512 less 64 bits.
- Append 64 bits of the input length of binary form.

Step 2:

- Create hash values (h) and initialize the first 32 bits with the square root fraction of the first 8 primes.
- Create round constants (k) and initialize the first 32 bits with the cube root fraction of the first 64 primes.
- Create a message schedule (w[0 . . 63]) with 32 bits of input word starting from index w[0] and the remaining index initialized with zero and modify them with the algorithm given below:

- Initialize $x = 0$;
- Loop L1:**
- set $i = w[x]$;
- set $s0 = (w[i-(X-1)] \text{ rightrotate } ((X-1)/2))$;
- set $s0 = s0 \text{ xor } (w[i-(X-1)] \text{ rightrotate } 18)$;
- set $s0 = s0 \text{ xor } (w[i-(X-1)] \text{ rightshift } 3)$;
- set $s1 = (w[i-2] \text{ rightrotate } (X+1))$;
- set $s1 = s1 \text{ xor } (w[i-2] \text{ rightrotate } (X+3))$;
- set $s1 = s1 \text{ xor } (w[i-2] \text{ rightshift } 10)$;
- set $w[i] = w[i-X] + s0 + w[i - ((X-1)/2)] + s1$;
- set $i = w[x+1]$;
- $x = x+1$;
- if** ($x < 63$) **goto** L1;
- END

Step 3:

- Create variables a, b, c, d, e, f, g, and h and initialize them with hash values h0, h1, h2, h3, h4, h5, h6, and h7, respectively.
- Chunk loop with 512 bits block.

- Initialize $i = 0$;
- Loop L2:**
- set $s1 = (e \text{ rightrotate } 6) \text{ xor } (e \text{ rightrotate } 11)$;
- set $s1 = s1 \text{ xor } (e \text{ rightrotate } 25)$;
- set $Ch = (e \text{ and } f) \text{ xor } ((\text{not } e) \text{ and } g)$;
- set $t1 = h + s1 + Ch + k[i] + w[i]$;

- set $s0 = (a \text{ rightrotate } 2) \text{ xor } (a \text{ rightrotate } 13)$;
- set $s0 = s0 \text{ xor } (a \text{ rightrotate } 22)$;
- set $Maj = (a \text{ and } b) \text{ xor } (a \text{ and } c) \text{ xor } (b \text{ and } c)$;
- set $t2 = s0 + Maj$;
- set $h = g$;
- set $g = f$;
- set $f = e$;
- set $e = d + t1$;
- set $d = c$;
- set $c = b$;
- set $b = a$;
- set $a = t1 + t2$;
- set $i = i + 1$;
- if** ($i < 63$) **then goto** L2;
- END

- Add a, b, c, d, e, f, g, and h with hash values h0, h1, h2, h3, h4, h5, h6, and h7, respectively.
- Append all the hash values respectively.

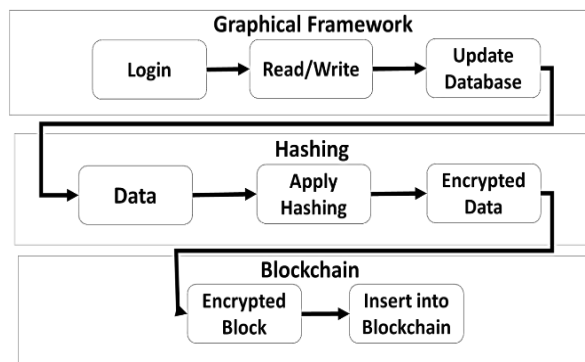


Figure. 1 Block diagram of the proposed model

the students are getting the job to which company.

The usual procedure of student information storage is based on a traditional database system, but the system we proposed not only implements Blockchain technology in this sector but also makes a base connectivity platform for job seekers and job providers to collaborate. We have used the consortium technique which is a combination of a public and private Blockchain, some parts of the database remain private, and only some authentic shareable documents are shared with the collaborators. In other cases, this type of consortium Blockchain technology has not been applied to any additional base for collaborating with an additional professional networking base.

First, every user must be logged into the graphical model system, as presented in Fig. 1. Then,

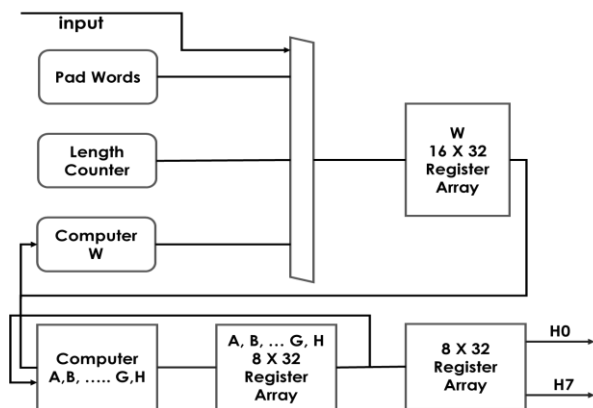


Figure. 2 Block diagram of SHA-256

they can read or write the data in the system based on their type of account. After every modification or change, the database must be updated (Fig. 1). The data will then pass through the hashing algorithm. Finally, the encrypted blocks are inserted into the Blockchain.

According to the SHA256 hashing algorithm, it encrypts the data and divides it into several parts, as well as multiplying it with several hash values after some pre-processing. Finally, concatenate the hash values together, creating a long-hashed value. As a result, the original data is completely unreadable. As it will be applied before passing the block into the Blockchain for each block, so this cryptographic hashing algorithm makes hashed messages or data completely unreadable, which provides more security for the documents. The visualization description is given in Fig. 2.

There are three types of accounts for users. Only an admin can create or delete an account if necessary. First, a user needs to provide all the required information to the admin. After investigating that, if the information is valid, the admin creates an account based on the user's requirement. A user can be a teacher, student, or company manager.

This framework model is implemented in the PHP language. In this model, there are many security systems to avoid data manipulations. There are many restrictions based on the type of user.

1. take *User* input
2. **if** (*User* Authentic and *User* is teacher)
3. **goto** L1;
4. **else**
5. **goto** L2;
6. L1:
7. show all student's documents.
8. show all job's documents.
9. **if** (*user's university = student's university*)
10. **goto** E1;

11. **else**
12. **goto** L1;
13. **goto** L2;
14. E1:
15. update student's document.
16. **goto** L1;
17. L2:
18. **END**

Here, in the above algorithm, it is ensured that no teacher can manipulate student documents from other universities. They can modify only their own university student documents. However, this type of user can view every student's document and job circular.

1. take *User* input
2. **if** (*User* Authentic and *User* is company)
3. **goto** L1;
4. **else**
5. **goto** L2;
6. L1:
7. show all student's documents.
8. show all job's documents.
9. create job circular.
10. **goto** L2;
11. L2:
12. **END**

Here, in the above algorithm, it is ensured that only the manager of a company can have the access to publish a job. However, this type of user can view all student documents and job documents.

1. take *User* input
2. **if** (*User* Authentic and *User* is student)
3. **goto** L1;
4. **else**
5. **goto** L2;
6. L1:
7. show all student's documents.
8. show all job's documents.
9. **if** (*user's profile = student's profile AND document ≠ teacher's document*)
10. **goto** E1;
11. **else**
12. **goto** L1;
13. **goto** L2;
14. E1:
15. update student's document.
16. **goto** L1;
17. L2:
18. **END**

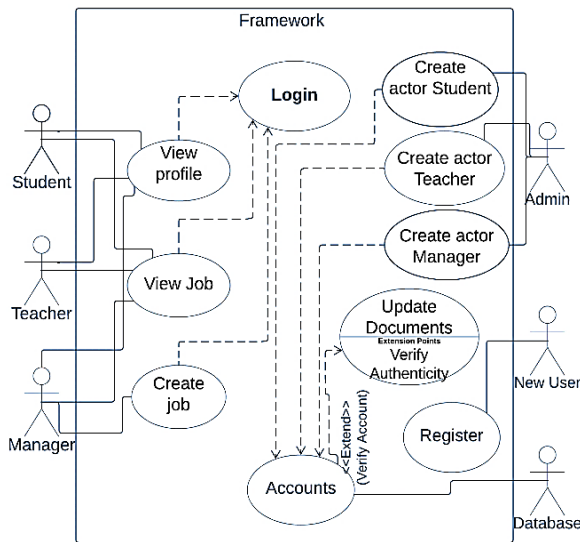


Figure. 3 Use Case Diagram of the framework model

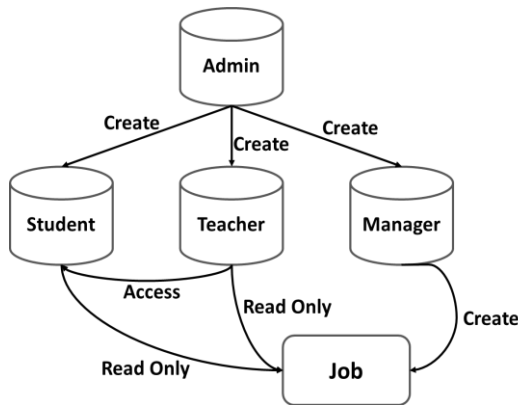


Figure. 4 Control flow diagram of the framework model

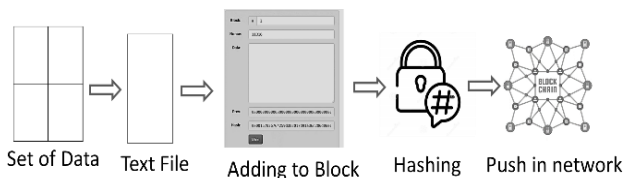


Figure. 5 Block diagram of the Blockchain model

Here, in the above algorithm, it is ensured that no student cannot manipulate their document which has access to the university like marks, grades, CGPA, earned credit, etc. They can modify only their document that has access to name, address, phone number, or own resume. However, this type of user can view every student’s document and job circular.

Finally, we combine both the Blockchain model and the graphical framework model for the proposed model. The graphical framework model ensures the security and authenticity of the documents and users, as well as the Blockchain model, provides extra security for the documents.

4. Results and analysis

In this experiment, we have built a graphical framework with PHP language. There are different types of users, students, teachers, and managers. But there is only one admin user who has the privilege to create an account.

The restrictions are based on the type of user account:

1. A teacher can only update his own university student’s documents such as CGPA, earned credits, marks sheet, etc.
2. A teacher can read all student’s documents and all job documents.
3. A student can read and update their profile such as name, address, resume, etc.
4. A student can read only the job documents.
5. A student has no access to the documents of other students.
6. A manager can read all student documents and all job documents.
7. A manager can create a job only.

From the use case diagram (Fig. 3), we can identify the role of each actor. It will verify the points mentioned points for restrictions based on the type of user account in the system based on pseudocode in section 3. Also, Fig. 4 shows the control flow of the whole system for the graphical framework model.

As a result, according to (Fig. 3) and (Fig. 4), we can claim that it will reduce data manipulation and also ensure data verification. In (Fig. 5), we can see the block diagram of the proposed Blockchain model.

If we analyze, the system contains the final step-by-step process of how data is inserted into the Blockchain. Our generated framework will provide a set of data after each profile creation and after every transaction or update made. This data will first be stored in a database which is primary data storage, and a trigger will be implemented to compile the data into a text-based document. After that, the data will be read and composed into a block of the Blockchain. Furthermore, the block will be hashed using the Algorithm 1 SHA-256 function, and the encrypted data will be inserted into the Blockchain network.

In the figure shown above (Fig. 6), we can see the sequence diagram of the model, which shows how the process will work in the system. It ensures that to use the system, users must be logged in. It also ensures that for every update or modification, the user must be authentic to do so. Also, it also verifies that for

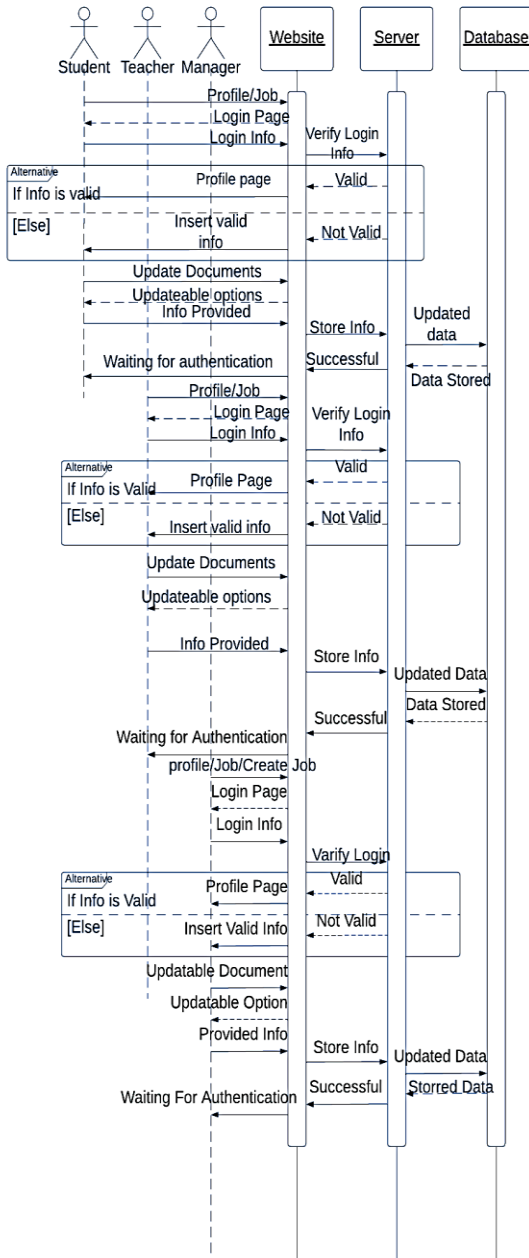


Figure. 6 Sequence diagram of the framework model

every change, the database must be updated. All these verifications confirm the data security before inserting the Blockchain.

4.1 Data collection

As the graphical framework model is a web-based model, all data will come from the users. Users provide their information and documents in the web-based framework model, which will be stored in the database first. These data will pass for further processing.

4.2 Model achievements

1. **Time Consumption:** This process will consume less time to validate and authenticate.
2. **Document Security:** This process will enhance document security as mentioned in Fig. 3, Fig. 4, and Fig. 6.
3. **Fraud Reduction:** This process will reduce fraud for the certification system, as data will be encrypted (Fig. 2 and Fig. 6) and only an authentic person has the privilege to access it.
4. **Usage of Consortium Blockchain:** It is one of the few concepts of Blockchain which has used consortium Blockchain as its base.

4.3 Model analysis and comparison

In this proposed model, there are two-step security protocols that are using a web-based security protocol and a Blockchain security protocol. These protocols can ensure the security of the proposed model. Additionally, as documents and data are taken using the Web-based framework, there are some high restrictions given on the basis of the types for reducing document fraud, which algorithms are described in section 3.

On the other hand, our proposed model uses consortium Blockchain technology. Throughout our system, companies can not only validate the certificates but also post job openings to notify the students as well. Moreover, it provides an inter-university communication facility for migration as well. Finally, our model proposes a system that contains a web-based security protocol and a Blockchain security protocol for ensuring additional security. So, we can conclude that our system is much more stable and better than the existing ones.

Finally, from Table 1, we can conclude that all have implemented public Blockchain technology as their system's Blockchain backbone. Moreover, they have implemented their entire network just to give companies or employers a validation system. Furthermore, most of their security system is based on just Blockchain security protocol. And finally, none of the institutes provide inter-university communication. Our proposed model uses consortium Blockchain technology. Throughout our system, companies can not only validate the certificates but also post job openings to notify the students as well. Moreover, it provides an inter-university communication facility for migration. Our model proposes a system that contains a web-based

Table 1. Performance comparison

References/Model	Block chain Type	Company Inclusion	Multiple University Inter Communication	Security Assurance
[14]	Public	Only Validation	Not Available	Centralized Authority and Blockchain Security
[15]	Public	Only Validation	Can Access the Network	Blockchain Security
[7]	Public	Only Validation	Not Available	Blockchain Security
[8]	Public	Only Validation	Not Available	Blockchain Security
Proposed Model	Consortium	Validation and Job Creation	Available	Web-Based Security and Blockchain Security

security protocol and a Blockchain security protocol for ensuring additional security. Therefore, we can conclude that our proposed system is much more stable and better than the existing ones.

5. Conclusion

Blockchain is not only a buzzword for technology and safety but also a need for the future of the world. The problem the world is facing right now is the trust issue. The idea of Blockchain comes from creating a tamper-proof system. Blockchain does not need to be handled by any third party, is safe and efficient, saves everyone from extra costs for authentication and verification, saves a lot of effort, and time and also, most importantly, is a decentralized process. Blockchain can be used in education to ensure sensitive data is safe and for security purposes. The possibilities and opportunities that Blockchain brings to the education sector are unimaginable. In this framework, our idea is to combine different institutions and keep all documents of the institutes and students safe in the Blockchain-based system. We can also upgrade this system as per need in the future.

In our whole project, we look to add a reward point for our future implementation. The reward points will be added between the universities and companies. Our research work will contribute to society to create a system where all educational documents will stay as digitalized data in a temper proof Blockchain network. As a scientific contribution, we are trying to showcase a new idea for the implementation of Blockchain technology other than just cryptocurrency.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

Conceptualization, AWR; methodology, KI; software, OBAR and SM; validation, KI and SM; formal analysis, KI, RI and SM; investigation, KI and SM; resources, AWR; data curation, OBAR and SM; writing—original draft preparation, AWR, OBAR, KI, SM and RI; writing—review and editing, AWR, KI, SM, RI, OBAR and MSA; visualization, KI and SM; supervision, AWR; project administration, AWR.

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