Blockchain based Framework for Efficient Student Performance Tracking (BloSPer)

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***Abstract*—For maintaining sustainable economy, the government of Malaysia is working towards improvising the standards of education in higher education institutes. According to reports, around 32% of enrolled students in Public Universities of Malaysia are unable to graduate on time due to unknown reasons. To ensure more students graduate on time with high quality of education, continuous monitoring of the student is essential. Continual tracking will allow the student as well as the educator to analyze the weak performer at an early stage. Tracking the student performance manually is challenging but with the advancements in information technology, keeping a track of student performance has been relatively easier. Therefore, the fundamental aim of this paper is to present a novel blockchain framework for record keeping and student performance tracking. We name this framework BloSPer (Blockchain Student Performance Tracking System). BloSPer has an edge over the existing systems as current systems face problems of single point of failure and unreliable data. The proposed framework will enable the students and educators to track the performance of the students in a more convenient and transparent manner. Due to this, it will be simpler for them to analyze the reasons of a students' poor performance. Moreover, the data gathered through the system will be more reliable and worthy for data analytics because of tamper resistance provided through blockchain. This will result in much knowledgeable decisions by the institutions regarding improving the performance of each individual candidate.**

Keywords*—Blockchain; education; performance tracking; trackability; student data analytics; student monitoring

I. Introduction

A. Background

For any nation to progress, education plays a significant role and is therefore usually the main focus for most developed countries. This is because the advancement in any sector depends on the level of education. United Nations has listed quality education as the 4th out of 17 Sustainable Development Goals (SDG) for its 2030 agenda. Education has a long-term positive impact on a country's economic growth [1]. Education plays a vital role in Malaysia for building a resilient nation, encouraging the creation of a just society, and maintaining sustainable economic growth [2]. Thus, improvising education sector is one of the major concerns of the Malaysian government nowadays.

According to Malaysian Qualifications Agency (MQA) criteria for higher education has been set through a code of practice that includes, vision, mission and learning outcomes; curriculum design and delivery; student selection and support services; assessment of students; educational resources; continual quality improvement and more. Each institution is evaluated based on the standards to ensure high quality of education. However, the way each institution works towards achievement of those standards varies. Despite of providing high quality of education, demand on predicting student academic performance become more critical to improve the quality of education and assisting the students to achieve a greater performance in their studies [2].

One way that most of the higher education institutions maintain the standards and quality of education is through tracking the student performance in a classroom setting [3][4]. Keeping a record of student performance at regular intervals will enable an interactive learning environment and promote better educational outcomes for the students. Tracking and monitoring the performance of students from time to time throughout the course of an academic semester has a positive impact for both, the students and the educators [5]. This positive impact may include valuable insights to redesign the course for instructors, decisions for improving standards of education, effective intervention of students and collection of valuable data for further analytics processes (if any). The fundamental aim of performance recording and analysis is to ensure better education standards and improved student performance. In order to achieve higher quality education, it is the core responsibility of each individual student and the academic institute to ensure every student achieves expertise in his area of interest. To reach this goal, various tools are needed by the educators to identify students who are at a potential risk of academic failure and adjust their strategies of delivery education meeting the needs of those students. Moreover, it is also very important for students to know the areas that need further focus and hard work. With student performance tracking the educators and students can continually evaluate the effectiveness of teaching and learning environment in the class. The continual monitoring will help them make more informed instructional decisions.

Information technology has made it easy to do and achieve with the recent advancements. The record keeping and management are now shifting to an innovative technology named Blockchain [6]. A blockchain is a distributed ledger i.e. the ledger is spread among all peers in across the network, and each peer holds a copy of the complete ledger [7]. Fundamental features of blockchain include being, i)

distributed, i.e., disseminating the ledger across the network to restrict the tampering of data [8], ii) transparency [9], i.e., authenticity of each transaction is verified by participants via consensus [10] in the network, and iii) immutable [11], i.e., the data cannot be modified/altered. The technology of Blockchain is known to track and trace the data in a more efficient way then the traditional record keeping approaches.

B. Research Gap

Presently, various tools and techniques are being used to monitor [12] the performances of students, and to predict student grades [13]. However, to the best of our knowledge, there's no way of determining the causes of student failure, i.e., if a student is likely to fail, then what reasons are causing this failure. This information is mainly important as it highlights what an individual lacks. In order to ensure each student's academic success, it is important to adjust the learning materials according to their needs. This can be achieved by tracking history of the student. Existing information systems do not have a reliable track of student performance data. Therefore, in this paper, we intend to overcome this gap by using the cutting-edge technology of the blockchain networks [14]. The main contributions of the manuscript, in this regard, are elaborated in upcoming section.

C. Major Contributions

The major contributions of this research article are twofold: 1) the shortcomings of existing student performance tracking systems are discussed and, 2) blockchain based novel framework for student performance tracking system is proposed. This framework will record the performance of the students in a distributed ledger accessible by various stakeholders involved in the process. The transparency and traceability of the blockchain will ensure that the performance indicators are not tampered with and can be tracked as needed. Moreover, since blockchains are immutable, hence the data collected from the proposed framework will be reliable, tamper free and accurate. This data can further be used for data analytics to determine student behaviours in various educational applications.

D. Organization

The organization of rest of the paper is as follows: Section II, describes the state-of-the-art student performance tracking systems available in literature and describes the shortcomings of the existing systems and discusses how blockchain technology can be used to overcome these challenges. Section III enlists the design goals and reasoning behind the proposed design. Section IV entails the proposed framework BloSPer. Section V presents results and discussions of the proposed framework. The paper finally concludes in Section VI, and a few promising future research directions are suggested in Section VII.

II. Literature Review

According to Malaysian Educational Statistics report published by Education Data Sector [15] about 32% of the students enrolled in public universities, fail to graduate on time. Moreover, this report was further analysed, and it was found out that from 2016 and onwards, each year the budget being used on improvising the education sector is substantially increasing. In 2016 actual educational recurrent expenditure was around 40 Million MYR which increased to around 45 Million MYR in 2018. Despite of the substantial increase in the budget being spent on education (public universities only) the literacy rate did not have a considerable improvement. The overall literacy rate in subsequent years only increased by 0.8%. These insights highlight the importance of taking measures to analyze the reasons behind unsatisfactory performance of a student in higher educational institutes.

A. Existing Student Performance Tracking (SPT) Systems

For determining the success and worth of any educational institute, the number of students graduating [16] each year plays an important role. Not only students graduating but, the students graduating with better scores is also significant [17]. Some students, having a higher intellectual ability, are fast learners while others need more time and undivided attention of the instructor. To maintain the quality of education, many institutions use different tools and techniques to track the output of the students. This tracked output helps the educators to accommodate differing needs of students [18]. With the advancements in technology it has been easier for educators to keep a track of student performance using various factors like student attendance, exam, quiz and lab work score, timely submission of assignments [19] and many more. Recording these features can also be used to predict if a student is likely to pass an exam or fail. In [20] a study was conducted to predict the success rate of the candidate in an English exam. Besides that, scores were also predicted with the help of technology. Similar study was presented in [21] where different data mining techniques were used to predict if a student is likely to pass or fail. This kind of analysis is claimed to be useful for higher education institutes as it will help them analyze students at risk to take preventive measures in time. Several other studies [22][23] have also been conducted to try different methods to predict passing or failing of a student in a course. However, these studies fail to track back to the factors causing failure of a student. Although, it is desirable to know the tendency of a student to fail to prevent it in time, but existing systems and technologies are incapable of tracking and finding the flaws each student possess. The identification of these flaws can lead to build a foundation of more useful strategies to enable students cop up with their inabilities or other study related issues.

Keeping the record of student performance is a usual practice in educational institutes all over the world. Tracking plays a significant role in analysing whether the student is learning well or not. Not only it allows monitoring of the students but recording performance and behavioural patterns of students also help data analysts to predict future performance of the students with the help of information technology. This prediction is highly valuable as it helps educational institutes to take measures to improve the performance and learning ability of students [13], thereby uplifting institutional reputation.

B. Challenges in Existing SPT Systems

A lot of work is being done for tracking student performance. However, this work has various challenges and shortcomings in terms of data storage and retrieval that need

to be addressed for more efficient systems and for better learning of students. Some of these challenges are discussed as follows.

1) Lack of traceability: The most common problem with existing record keeping systems is lack of traceability [24][25]. This means that these systems usually depict the overall statistics of the student performance but fail to give a detailed insight on the history of student evaluation as a learner at various levels of study. This history is important as it determines when the student's performance started declining what factors caused it to decline. This information is significant for correct prediction of student future behavior [26]. Moreover, history tracing allows the educators to make more knowledgeable decisions for improving a certain student's learning ability and overall performance.

2) Single point of failure: Existing systems are built on centralized storages [27] [28]. This means that they have a single point of failure [29]. In case of a disaster or loss of data, it will be very difficult and almost impossible to retrieve back the data if backups are not properly kept.

III. Conceptualization of Proposed Blockchain based Student Performance Tracking System (BLOSPER)

A. Design Goals

Based on the problems found in literature with existing student performance tracking systems (as mentioned in previous section), we have devised a few design goals that must be present in the proposed system. These design goals are as follows:

1) The application must be decentralized to avoid any single point of failure.

2) The record of student submissions must be transparent and tamper proof.

3) The performance of each student must be easily trackable.

To accomplish this, we proposed a student performance tracking system based on the novel technology of blockchain networks.

B. Blockchain as a Solution

The idea of blockchain technology was introduced with the advent of bitcoin, popularly known cryptocurrency [14]. The technology eliminates the need of third parties for transactions and has been proven to be more time efficient as compared to the third-party hosted system [15]. Blockchain is a disruptive innovation based on distributed ledger technology. It is responsible for record keeping in a transparent ledger. The transparent distributed ledger makes it very convenient for the user to trackback even the tiniest form of information as all the data is chained into the blocks. Besides ease of tracking data, blockchain also ensures immutability of records. This implies that the once the data has been validated and stored into the blockchain, it cannot be tampered with, hence a blockchain based system is essentially hack proof. Blockchain has a number of benefits that will help the traditional student performance monitoring and tracking systems more efficient and meaningful. Some of these include:

C. Decentralized and Distributed Ledger

Since the data on a blockchain network is distributed among all the participating peers [16] therefore, the need of trusting a designated authority to control and supervise the chain is not needed. This provides a user a complete autonomy over his data. Any student using this system can completely rely on the system for accurate tracking and monitoring without any ambiguities. Moreover, the decentralization of storage [17] ensures that there is a very little to no chance of the data being misplaced. This ensures the integrity and security of the data to any deploying enterprise/institution.

1) Transparency: Another remarkable feature provided by blockchain technology is transparency. Anyone in the network can view the information as per their convenience. This reduces the chances of illegal transactions.

2) Better trackability: The data on blockchains cannot be altered or removed. This signifies that all the data that is present on the blockchain remains there and every new information is linked to the previous corresponding information. This enables the user to trackback the entire history of chained records from the storage. This history can present detailed insights on the performance of students through various events from the beginning of usage of the system. Since all the transactions in the blockchain are timestamped hence the time and data of submission for different assignments and tasks can also be inferred from the records. Such data can be very useful for data analytics and to examine the weak points in student performance that must be targeted for better learning of the student and overall education system.

3) Immutability: Immutability of the data and transactions in blockchain will ensure no student data is tampered with. This enables a greater trust of the stakeholders into the performance tracking system. Moreover, it guarantees that the data used by data analytics for prediction purposes is original and untampered.

Moreover, according to [7] the internet access to educational institutes is getting better with each passing year. This provides a stronger base for blockchains to be implemented without a problem. Therefore, with these wide variety of benefits and ease of internet access, blockchain-based student performance tracking systems can be successfully deployed in educational institutes thereby improving the education standards of the country.

IV. BLOSPER Architecture

A. Proposed Framework Components

Continual monitoring and tracking of students' performance is known to increase the efficiency of the students. In this paper, a novel framework for blockchain based student performance tracking (BloSPer) is proposed to keep the record of student performance on a blockchain network. The fundamental aim of this framework is to make

tracking the performance of students easier and more transparent. The traditional student monitoring and tracking systems are unable to trackback and identify the causes of student failure. The proposed framework will trackback to the entire performance history of the students to recognize the causes of performance lag in students. This ensures better strategies are devised to improve student learning ability and overall quality of education of an institution. The overall framework for the proposed BloSPer is shown in Fig. 1. The proposed framework has three major components i.e., User Interface (the front-end), Processing Layer and, Blockchain Layer. The functionality of each component is explained below:

1) User interface: As the name suggests, this component enables the users to interact with the blockchain system for information storage and retrieval. It captures information including login credentials, assignments, and other essential data from end user and sends it to processing layer.

2) Processing layer: This component consists of all the major modules designed for smooth functionality of BloSPer. The modules include i) Login Module, ii) Registration Module, iii) User Management Module, iv) Data Management Module and, v) Data Analytics Module. The data from front-end is received by processing layer and the query is forwarded to the corresponding module. The purpose of each module is elaborated as follows.

a) Login Module (LM): This module is responsible for ensuring if the login credentials entered by a user are authorised to use the system. Once the user is authorised, the module maintains a session so that the user does not need to login for every transaction triggered.

b) Registration Module (RM): The registration module enables the system administrator to register the records of students and instructors. No one can use the system unless administrator registers them using this module.

c) User Management Module (UMM): This module allows the administrator to add and delete the users from the system.

d) Data Management Module (DMM): This module is responsible for management of data, i.e., it enables the users to store the data into the chain and retrieve the authorised information from the blockchain.

e) Data Analytics Module (DAM): The purpose of this module is to download all the data for analytics purposes. These purposes may include predicting student academic performance, analysing instructor behaviour, and so on. However, it should be noted that this module is yet not a part of the implementation, currently it is only being proposed, hence it is colour coded in red to illustrate the difference between this module and the rest of the modules.

3) Blockchain layer: The third component is the blockchain layer. It provides the decentralised support for the proposed framework. Since blockchain itself cannot store huge multimedia files, hence this layer also provides blockchain compatible, decentralised storage.

B. Stakeholders

There are three kinds of stakeholders involved in the proposed system, i.e., the instructor or educator, the student and the administrative staff as shown in Fig. 2. The role of each stakeholder is described below:

1) Instructor

The main responsibilities of instructor include:

- Self-authorize to be able to use the system.
- Upload scores of exams, assignments, lab work and other tasks submitted by students.
- Track and trace the performance of students.

2) Student

The main responsibilities of students include:

- Self-authorize to be able to use the system.
- Upload assignments, lab work and other tasks assigned by the instructor.
- Track and trace their performance.

3) Administrator

The main responsibilities of students include:

- Self-authorize to be able to use the system.
- Add student data and grant those students the permission to access the system.

C. Features and Functionalities

The various other features the BloSPer offers for end users include the following:

1) Enabling students to upload assignments/tests/lab work and other assessment materials.

2) Enabling instructors/teachers to review the assessment materials uploaded by students and mark those.

3) Enabling instructors/teachers to award reward points to students. Students can further redeem these reward points for accessing paid teaching and learning materials.

4) Enabling institutional administrators to ensure that students and instructors are uploading and reviewing assessment materials on time.

5) Enabling institutional administrators to download reliable data for further data analysis and decision making on improving student performance.

System users need to use DApp to login to the system using their private keys and interact with the data stored on the chain. It can be noted that the framework has a module.

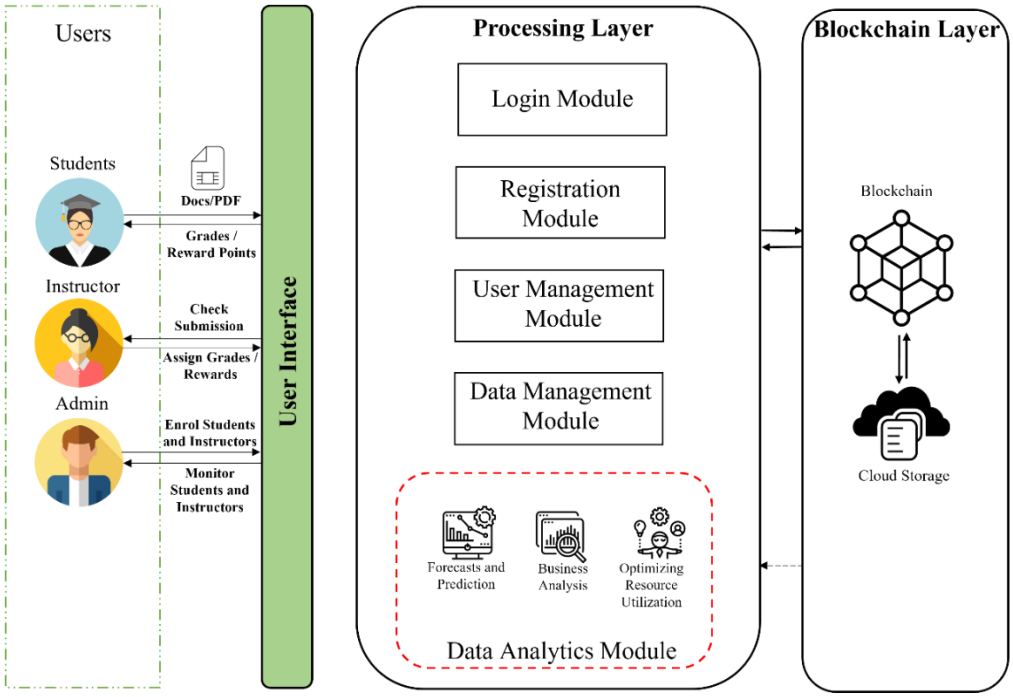

Fig. 1. Proposed Framework for BloSPer.

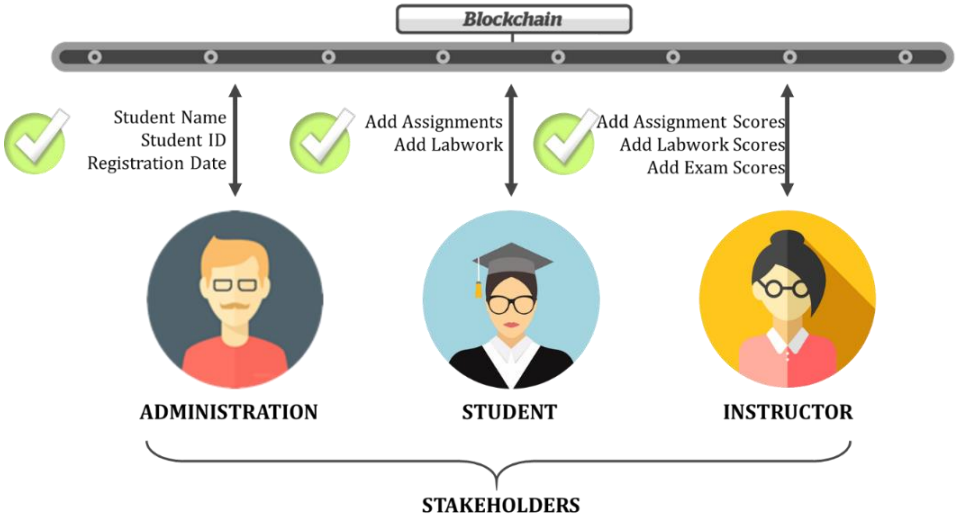

Fig. 2. Stakeholders in Student Performance Tracking System.

D. Interaction and Transaction Sequence

In this section, we describe how BloSPer transactions are executed and communicated between different stakeholders. A graphical illustration of the system usage is given in Fig. 3. The student will submit his assignment, lab work or other tasks in the form of a transaction in a block. The block must be then validated by all the participating peers in the network. Once the block is validated it is stored into existing blockchain network. Next, the instructor can forward the request for data retrieval. This request will again be validated by participating peers to check if the instructor is authorized to access the data or not. After the request has been validated, the data will be retrieved from the blockchain and sent to the instructor. After reviewing student assignment/lab work, the instructor will insert the relevant grade into the blockchain, which will again be validated by peers and the final data will be stored into the blockchain.

The same procedure will be repeated when student wants to access his grade or when the administrative staff wants to retrieve the data for official purposes.

For using this system, all users are required to identify and authenticate themselves using the private keys received upon registration. Initially, a predefined administrator will login the system. This login request will trigger login () function in LM, from where the LM will authenticate him by matching the user records stored on blockchain. Once the administrator is authorised, he may use the system to register different

participants (i.e., students and teachers/instructors) to use the system, by calling reg(uname, utype) function, where uname refers to the name of the users and utype refers to his role/type (student/teacher). Once the registration module receives the request from admin, it generates public and private keys for the users and returns the same to the admin. Now the student may use these keys to login and submit their assignments. This will trigger the function submit (title, type, desc, teacher) where title refers to assignment title, type refers to the type of file submitted, desc refers to description of the submission and finally teacher refers to the public ID of the instructor that the assignment is submitted to. Once the student has submitted the assignment, the teacher can login to his portal and view the assignment, mark the assignments and monitor student progress. This entire process is shown in Fig. 4.

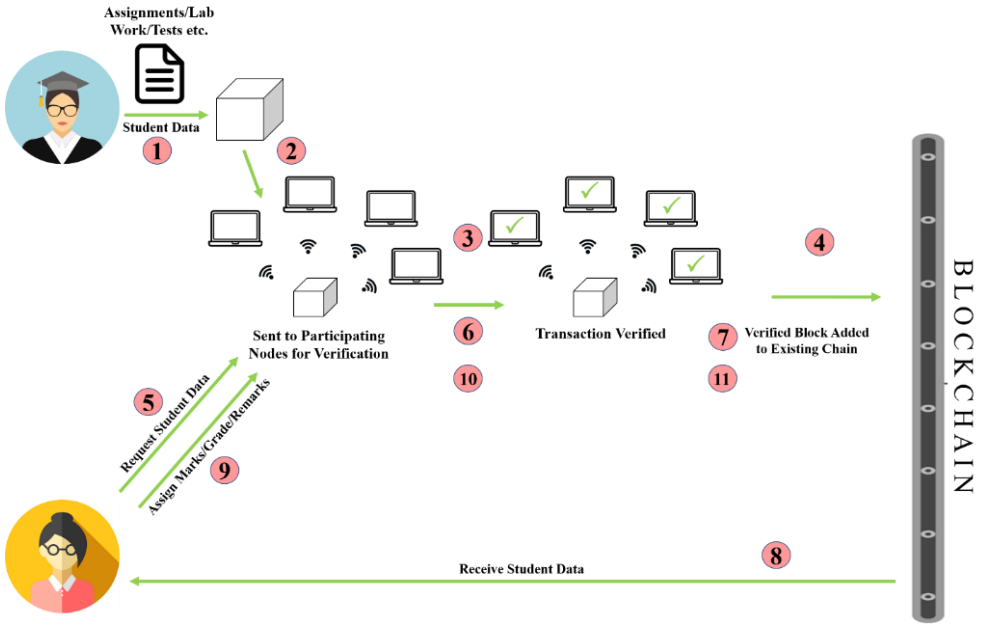

Fig. 3. Workflow of Students Performance Tracking Systems.

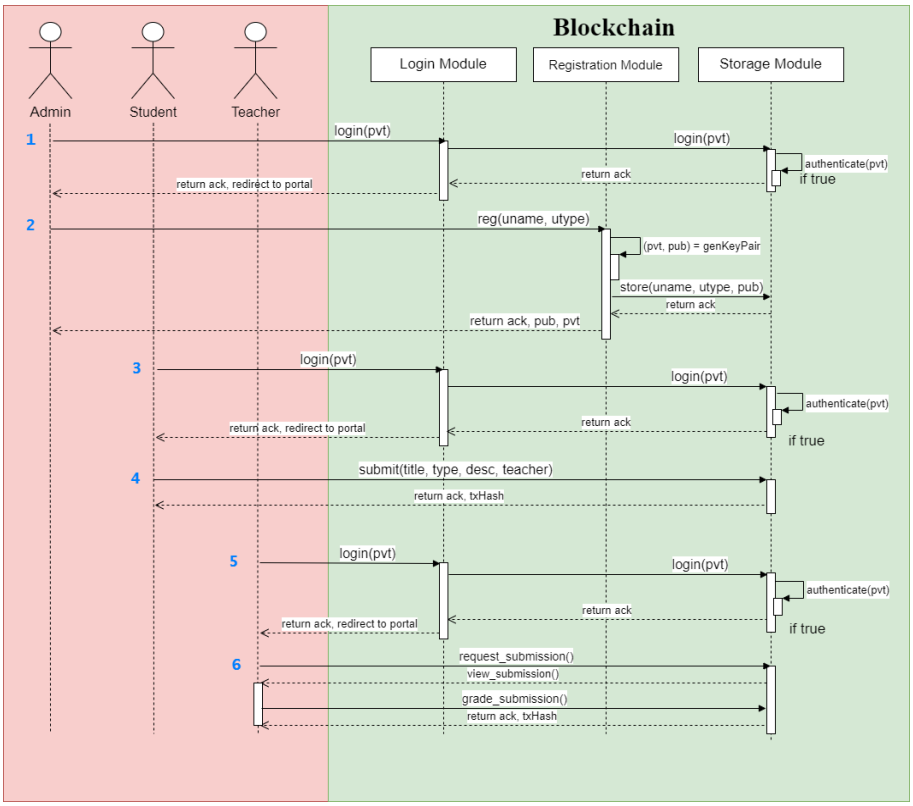

Fig. 4. Different Types of Transaction Flows in BloSPer.

E. System Architecture

The layered architecture of the proposed system is illustrated in Fig. 5. The proposed framework is divided into four layers: i) Infrastructure Layer, ii) Consensus Layer, iii) Protocol Layer and iv) Application Layer.

The first layer is the infrastructure layer facilitating all the required hardware components for the system including different kinds of nodes (i.e., simple, full, mining), storage and other network facilities. The function of the nodes is to send, receive, store and mine the transactions. Storage in the layer is responsible for storing the updated ledger after each verified transaction is added to the chain.

Followed by infrastructure layer, the proposed architecture consists of consensus layer. A consensus mechanism is an integral part of blockchain networks. It can be defined as a fault-tolerant mechanism that is used in blockchain systems to achieve the necessary agreement on a single data value or a single state of the network among distributed processes or multi-agent systems. Most widely used consensus mechanism include Proof-of-Work (PoW), Proof-of-Stake (PoS), Proof-of-Capacity (PoC), etc. This layer also includes smart contracts which are computer programs consisting of predefined set of rules and agreements among various parties involved in the blockchain network.

The third layer in the proposed architecture is the protocol layer. This layer deals with the protocols that are necessary for a transaction to flow through the network. Whenever a transaction is requested/initiated in a blockchain network, it must first be signed with digital signature of the sender and public key of the receiver. Then the transaction is encrypted using hash functions. This layer is also responsible for handling various protocols required for decentralized data storage.

Finally, there is an application layer. The function of application layer is to provide the user an ease of interacting with the data and communication within blockchain. This is a host layer for network application to make the usage of the system more convenient to the stakeholder.

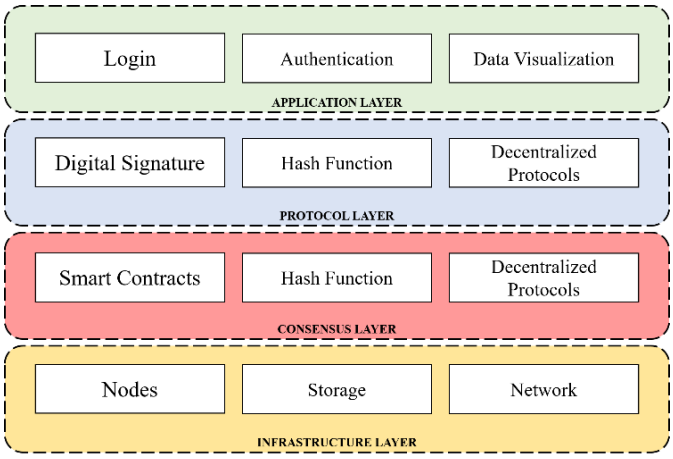

Fig. 5. Student Performance Tracking System Architecture.

V. Simulation Results and Discussion

In this section, the simulation results are described and discussed. The experiments are simulated on Intel(R) Core (TM) i7-10510U processor with 8GB RAM and 2304 MHz clock speed. The prototype is implementation using NodeJS programming language and executed using Visual Studio Code. The main screen to use the system is shown in Fig. 6.

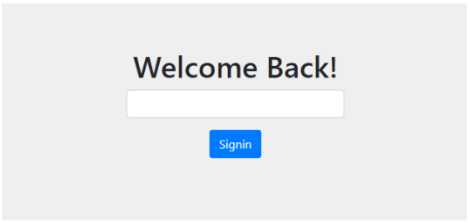

Fig. 6. Welcome Screen of BloSPer.

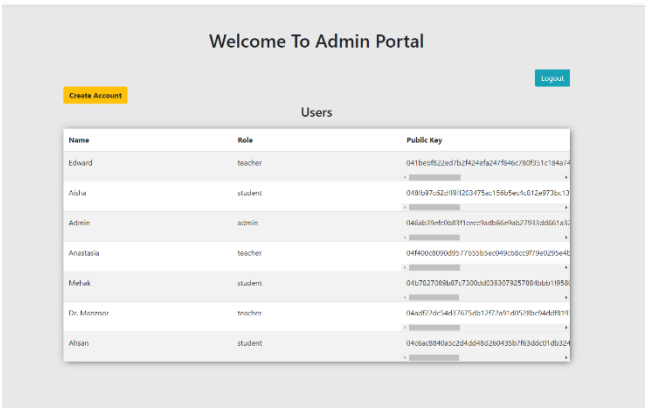

Fig. 7. Admin Portal.

This screen requires the admin to sign in. The information of the admin has already been added to the system. Once the admin logins using his private key, the admin will be redirected to the admin portal as shown in Fig. 7. On the portal, the admin can see all the users of the system, their roles/types and their public keys. Here, the admin has an option of register more students and teachers to the system using create account button. Moreover, the admin portal has an option named "Block Explorer" which will enable the admin to retrieve information about a user, a block, or a transaction by using their corresponding hashes as shown in Fig. 8.

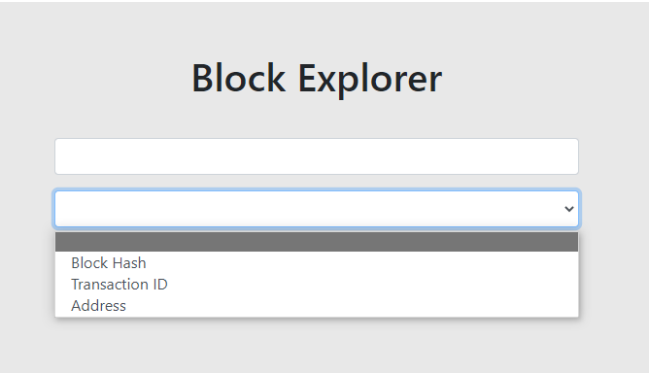

Fig. 8. Block Explorer – Admin Portal.

As soon as the admin enters the hash and selects the category that the hash belongs to, the entire information about that hash will be visible to the admin for monitoring purposes as shown in Fig. 9.

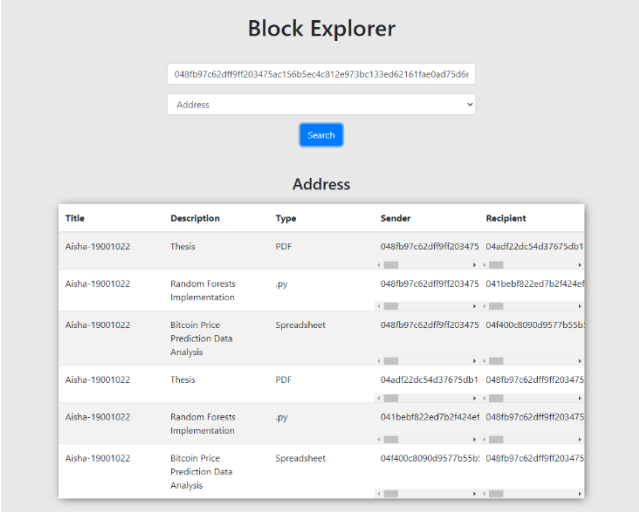

Fig. 9. Retrieving user information – Admin Portal.

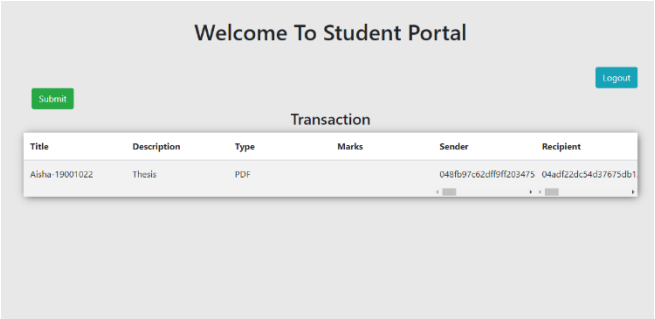

Fig. 10. Student Portal.

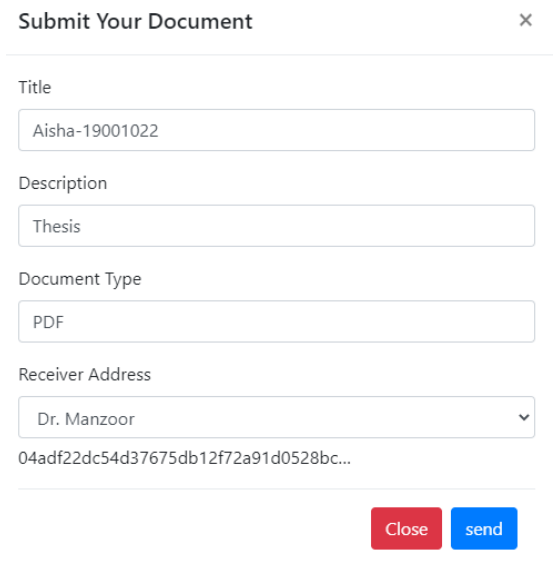

Fig. 11. Task Submission – Student Portal.

The second stakeholder of the proposed BloSPer is the student. As soon as the student logins, he will be redirected to the student portal as shown in Fig. 10. To add a file, the student must click on submit button, which will open a pop-up window for submission as shown in Fig. 11. At the time of submission, there will be no marks assigned as shown in Fig. 10. Once the student has submitted the work, the teachers can view and mark it on their portal as shown in Fig. 12. and Fig. 13. respectively.

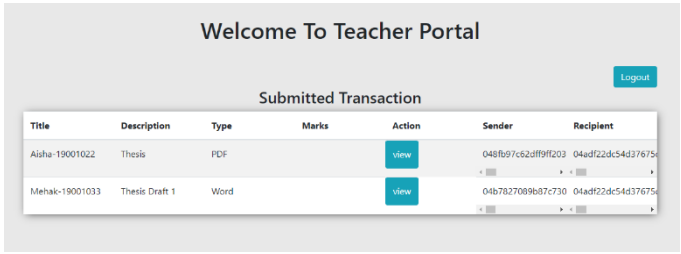

Fig. 12. Viewing Task – Teacher Portal.

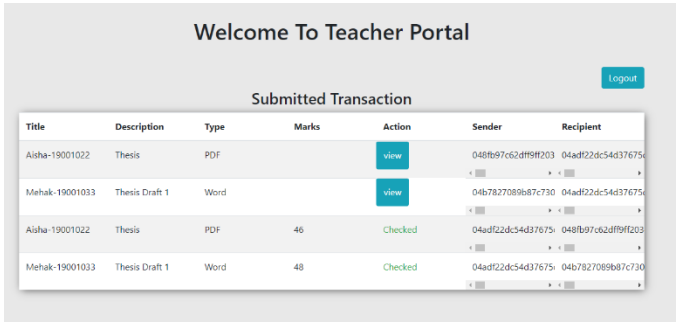

Fig. 13. Marking Task – Teacher Portal.

The data retrieved from the usage of this system will not only provide information regarding student marks but will also describe the student behavior in terms of submission time and other patterns. It will also monitor the behavior of teachers while marking. All this data can further be used to develop insights to improvise student academic performance.

VI. Conclusion

High quality education has a great significance for progress and prosperity of any nation. For socio-economic, political and industrial growth and well-being of a country, it is very important for its people to be well learned. Various institutions are striving towards ensuring that their students are well skilled and well trained. To achieve this, these institutions are trying and testing several methods to improve the performance of the students lagging due to unknown reasons. One such widely adopted practice is monitoring and analyzing the performance of students with the help of information technology. Literature shows that there is some remarkable work done in the domain for recording student's past and current behavior and predicting the future performance to improve the quality of education and overall student performance. However, these systems present statistical analysis only. Substantial amount of consideration is not given to trackback to the causes of students' poor performance. Our proposed framework utilizes the features of blockchain to overcome these issues. It provides a platform for

student performance monitoring in a decentralized environment. Due to immutability and trackability of blockchain, the entire history of student performance is stored which cannot be removed or altered. Hence, it provides a clear picture of student's academic standing. Using this information, important actions could be taken in order to optimize and improvise the learning experience for the students.

VII. Future Work

In this paper, we have presented a novel framework based on innovative technology of blockchain that will not only record student performance but also trace back to the causes of student failure, which is essential to devise better strategies to improve the overall education standard of the institute. However, the given system has some limitations due to time and resource constraints, hence we propose the following future research directions to improvise the study given in this paper:

1) Incentive based learning: Another simple feature could be added to BloSPer where teachers award the students with some reward points based on their good performance. These reward points can later be redeemed to access paid research and study materials, or to apply for certain courses/certifications to further enhance their capabilities.

2) Incorporation of IPFS/CouchDB for multimedia storage: Interplanetary File Storage System or CouchDB are two decentralized storage platforms. These platforms can further be integrated with the proposed system for storing different kinds of multimedia files.

3) Data analytics: The data analytics module in the proposed framework has not been implemented in the tested prototype yet. Hence, the module can be implemented to automatically visualize the data and retrieve insightful information. This is a great promising research direction as it will hugely benefit data analytics industry besides improvising student performance.

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