MAKERERE UNIVERSITY

COLLEGE OF COMPUTING & INFORMATION SCIENCES

STORAGE OF ACADEMIC RECORDS USING BLOCKCHAIN TECHNOLOGY
By
CSC 19-03

DEPARTMENT OF COMPUTER SCIENCE
SCHOOL OF COMPUTING AND INFORMATICS TECHNOLOGY

A Project report Submitted to the School of Computing and Informatics Technology For the Study Leading to a Project Report in Partial Fulfillment of the Requirements for the Award of the Degree of Bachelor of Science in Computer Science Of Makerere University

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April, 2019

Declaration

We Group CSC 19-3 do hereby declare that this Project Report is original and has not been published and/or submitted for any other degree award to any other University before.

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Dedication

We dedicate this report to the Almighty God without whom we can do nothing. We further dedicate it to our parents and guardians for their unceasing and selfless support throughout our stay in this university.

Acknowledgement

We are deeply indebted to our project supervisor Professor Engineer Baino-mugisha whose unlimited steadfast support, expertise and inspirations has made this project a great success. In a very special way, we thank him for every support he has rendered unto us to see that we succeed in this challenging study.

Special thanks go to our friends and families who have contained the hectic moments and stress we have been through during the course of the research project.

We thank the school for giving us the grand opportunity to work as a team which has indeed promoted our team work spirit and communication skills. We also thank individual group members for the good team spirit and solidarity.

Abstract

Storage of Academic Documents using Blockchain arose after the realization of the bureaucracy and loopholes involved in obtaining academic records in educational institutions all over the country. The application is aimed at ensuring easy access, distribution and security of academic transcripts attained by students.

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Chapter 1

Introduction

1.1 Background

There have been efforts to streamline delivery of authentic information about students who attend higher institutions of learning.

In a bid to achieve this, Makerere University, like any other institutions, uses a conventional online system to manage students' results. Upon admission to the university, an account is opened for each student through which they can can view their progressive academic records which are uploaded by a centralized administration that comprises of the school registrars. For security purposes, users are required to enter credentials i.e Student Number / Registration Number and Password. Through this, only authentic users can access the system. The use of this online system has eased students' access to their records as opposed to the formally crowded notice boards where results were pinned. For purposes of security, the system runs on the university's intranet network.

Upon completion of their study at the University, students' are awarded with an inventory of the courses taken and grades earned throughout their course of study. This comes in the form of an academic transcript. However, since the issued transcript is in hard copy, this comes with a number of complications. For example security risks, duplication and forgery, ease of access and distribution.

Recently one of the breakthroughs in technology has been the management of records belonging to a group of people using a decentralized system. One may wonder how this is possible. Well, this is done using a technology known as blockchain.

A blockchain is a growing list of records which are linked using cryptography[1]. Blockchain can not only be used to store records, but also be used for their secure manipulation. By design, a blockchain is resistant to modification of the

data stored on it. It is "an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way".

In the context of Makerere University for example, blockchain technology would be a good alternative to storing syudents' transcripts. In addition to issuing transcripts in hard copy form, using blockchain guarantees one some extra features that would better the management and storage of students' records. For example [2] :

Transparency Both parties who are interested in viewing academic credentials can see them on the blockchain. This ensures that only people with ownership rights can make decisions about who has access to particular information.

Immutability Blockchains are the most secure source for storing the information right now. They rely on the integrity of the network to ensure the authenticity of the stored information. Thus, academic certificates stored on the blockchain are immutable.

Disintermediation - Using the blockchain to store and share academic credentials helps us bypass the need for a central controlling authority that manages and keeps records. This makes the overall process of storing credentials more trustworthy as there are no middlemen involved.

Collaboration Once the information becomes available on the blockchain, it is much easier to ascribe ownership, and therefore safer to share the information without the fear of this information being compromised.

In this project, we intend to build a blockchain application that will aid the management of students' records at Makerere University.

1.2   Problem Statement

In an article published by the Daily Monitor in March 2017, 87 per cent of graduates cannot find jobs. "According to National Planning Authority (NPA) statistics released from [6 12, March 2017], 700,000 people join the job market every year regardless of qualification but only 90,000 get something to do."[3] One of the major causes of this is the problem of fake academic papers. It is a well-known secret that while a considerable number of Ugandans tender in doctored documents to get employment, a huge number of people with genuine papers remain unemployed.

Currently, it is pretty easy to obtain a forged transcript. For as little as $100, one can acquire a fake transcript that required another person four years of study. Unfortunately for employers, it is not so obvious to tell the difference between authentic and counterfeit.

This project aims at tackling the above-mentioned shortcoming with a focus on the results testimonial issued to a student of the university. Enforcing means of verification of academic documents is our proposed approach to reducing these rates of unemployment, especially for university graduates.

1.3 Main Objective

The overall aim of this project is to improve authenticity of documents by implementing block chain technology.

1.3.1 Specific Objectives

The specific objectives of the study were:

- To ensure safety of students' records. Unlike paper-based records that can easily get lost, once put in block chain, the students' grades will be safe.

- To create an open, distributed catalog that makes it easy for students to share their transcripts with whom they please.

- To provide a medium of verification that can be used by employers in telling a true transcript from a counterfeit.

1.3.2 Scope

The challenge mentioned in the problem statement above is broad and cuts across a number of institutions of higher learning in the nation and even beyond borders. For this project however, the focus will be on Makerere University Main Campus located in Kampala, Uganda. Furthermore, the project will focus on issuance of the academic transcript to a student of the university among other documents.

1.3.3 Significance

In the year 2010, the African Development Banks (AfDBs) Partnership Forum had put national unemployment figures at 83 per cent. The World Bank had at the same time put youth unemployment in Kampala alone at 32.2 per cent and unemployment among university graduates in Kampala at 36 per cent.[4]
To many university students, this is a problem that may cause a lot of stress and worry among the majority. However, every problem has in it the seeds of its own solution.

No one would like to eat half baked bread leave alone the raw dough. The

employment industry is flooded with so many employees that have barely attained the knowledge to perform the tasks they are given simply because they were able to forge documents and convince their employer that theyre capable.

This project is aimed at closing such loop holes that allow people to get away with forged academic documents.

For employers, block chain technology will avoid them having to spend valuable time checking candidates' educational credentials by having to call universities or to pay a third party to do the job.

A country's economy becomes more productive as the proportion of educated workers increases since educated workers can more efficiently carry out tasks that require literacy and critical thinking. Uganda has an adult literacy rate of about 75%[5]. By providing them with the deserved access to employment and to participate in building the society, the economy will be much more productive and the country's GDP will be boosted.

Chapter 2

Literature Review

2.1 Background

Storing and verifying students' academic transcripts can be costly and time-consuming for academia, students and businesses alike. Through this project, we look to turn to blockchain technology for a solution. But first of all, let us start with a review of the blockchain technology and its current applications.

Bitcoin which is a peer to peer electronic cash system was revealed to the world in 2008 by Satoshi Nakamoto whose identity is still unknown and was offered to the open source community in 2009. The decentralised nature of the technology used by bitcoin came to be known as blockchain.
 Bitcoin uses cryptographic proof instead of the trust-in-the-third-party mechanism for two willing parties to execute an online transaction over the Internet. Each transaction is protected through a digital signature, is sent to the public key of the receiver, and is digitally signed using the private key of the sender. In order to spend money, the owner of the cryptocurrency needs to prove his ownership of the private key.
The entity receiving the digital currency then verifies the digital signature, which implies ownership of the corresponding private key, by using the public key of the sender on the respective transaction.
Each transaction is broadcasted to every node in the Bitcoin network and is then recorded in a public ledger after verification. Every single transaction needs to be verified for validity before it is recorded in the public ledger.

Storing documents on the blockchain

Up until 2014, blockchain did not seem to have much potential independent of bitcoin. In 2014, some people realised other potential uses of blockchain in disciplines like supply chain, healthcare, insurance, education among others.

Figure 2.1: How blockchain works

Over the past several years, there has been a keen interest in how we can use blockchains for storing documents.

There are two main ways to store a document on the blockchain. One option is to store the entire document itself on-chain. Alternatively, one can store a hash of it on the blockchain.

- **Storing Entire Document** - Storing a whole document on-chain is possible with certain blockchains.
  However, we found out that it is rarely a good idea because of something called access latency. Fully decentralized public blockchains have thousands of nodes and this means it takes long for network users to upload and download files, such as documents.

- **Storing a Hash** - This method involves storing a documents hash on-chain while keeping the whole document elsewhere. The document could be stored in a centralized database or on a distributed file storage system. The document can be put through a secure hash algorithm like SHA-256 and then the hash is stored in a block. We find this to be the most efficient method as it saves a huge amount of space and cost. Additionally, using the hash, one is able to tell if someone tampers with the original document.

There are few projects that focus on documents alone right now. Most are built around decentralized file storage, which includes documents.

One project that is focused specifically on documents, particularly signed doc-

uments, is Blocksign[6]. This uses the hash method. A user will sign the document and send it to Blocksign, where it is then hashed, and the hash is stored on the Bitcoin blockchain.

Other cryptocurrency projects designed for decentralized storage more generally include Siacoin, Storj and Cryptyk.

Siacoin[7] - uses their distributed network to store an encrypted version of one's document. The Siacoin network is comprised of hosts who provide storage and clients who desire storage. Clients and hosts agree upon contracts detailing the commitments made by the storage providers. Sia's own proof of work blockchain stores these contracts.

Storj[8] - runs atop the Ethereum blockchain. A hash of the document is stored within a hash table on-chain. Additionally, its distributed network also stores your document.

Cryptyk[9] - an enterprise-focused platform to store documents, uses a blockchain more distantly than all of the above . You do not store any documents or hashes on-chain. Instead, a distributed cloud system stores the documents. The platform only uses a blockchain to manage and referee document access and sharing.

Described below are not only some of the contributions, but also weaknesses and gaps that are associated with this technology.

Contributions

Because decentralized applications run on the block chain, they benefit from all of its properties, which include:-

- **Immutability** A third party cannot make any changes to data.

- **Corruption & tamper proof** Apps are based on a network formed around the principle of consensus, making censorship impossible.

- **Secure** With no central point of failure and secured using cryptography, applications are well protected against hacking attacks and fraudulent activities.

- **Zero downtime** Apps never go down and can never be switched off.

For an example of the contribution of this technology, we look at the University of Nicosia in Cyprus, which is using the technology to record students' achievements. According to George Papageorgiou, a digital currency lecturer at the university, the technology is proving popular. He had this to say to CNBC News:
"We've only encountered enthusiasm in the practical uses so far and students

are glad to be able to verify, with their new knowledge and the blockchain, that their digital certificate is genuine and that it cannot be recreated.
We believe this instills confidence in both students and potential employers that (they) can check on their own, whether a presented certificate is real or not".[10]

This is proof that the implementation is already reaping fruits in some institutions around the world.

Weaknesses and gaps

However, despite all the possibilities offered by blockchain, there have been various challenges associated with it.

We observe challenges in both the perspective of the end-user, and we, the researchers. From the users view, according to Donald Clark [11], an EdTech entrepreneur and advisor of EdTech companies, some public sector organizations just dont like the innovation and stick to their institutional silos. This is basically because the technology has not been around for a long time which makes many potential users have doubts about its possibilities. To overcome this, we intend to train the parties in these institutions on how to use this technology and also show them the advantages.

From our research perspective, the major challenge is that the subject of study is of a relatively early stage. Blockchain technologies are under active development globally, and there may be recent advances that impact our findings.

In conclusion, it is important to note that blockchain is a technology that clearly has applications in the world of learning at individual, institutional and international levels. It is relevant in all sorts of contexts: schools, colleges, universities among others.

One thing we know for sure is that students have their eyes open and are looking for alternatives. Perhaps, like Bitcoin, the blockchain revolution will ultimately come from left of field.

Chapter 3

Methodology

3.1 Introduction

As stated earlier in the document, Unauthentic academic documents cause a great deal of trouble in the employment industry and a country's economy. The need for a more secure way of dispatching academic results is the major drive to the operation of this project.

This chapter contains a description of the techniques, methods and tools used during the research process. Also contained in this chapter, is a description of the implementation, testing and validation of the system.

3.2 Data Collection

The data collection process in this project was done through interviews with the various stakeholders of the system for example the students and administrative assistants at different colleges of the university. Document reviews were also done in the process of data collection.

From the vast number of stakeholders, sampling was done using the systematic sampling technique. This is a type of probability sampling where every element of the sample space has an equal chance of being picked.

3.2.1 Interviews

This is a one to one discussion between the project team and the expected users of the system. An advantage this method has over many others is that the interviewer gets first-hand information. This method is also qualitative in nature and helpful in validating the already gathered information. However, there is a possibility of the interviewee giving false information regarding particular

aspects based on their emotional state.

The interviews were carried through a one on one discussion with the interviewees.

Reasons for using this method

- Quick feedback from respondents cuts short on the time of requirements collections.

- There is a possibility of asking questions that are not included in the interview script.

- This technique allows respondents to describe what is more important to them.

3.2.2   Observation

As a source of additional information, we carried out some observations of the current results management system used by the university. This, we did by accessing the student portal(ar.mak.ac.ug)used for results.

The major aim for our observations was to get qualitative information about the existing system that handles students results.

Reasons for using this method

- Provides access to situations and people where questionnaires and interviews are inappropriate to use.

- Strong on validity and in-depth understanding of the design problem.

- Good for explaining meaning and context.

3.2.3   Document Review

Through literature review, we collected information from already existing related research. This research was done on similar systems to the one involved in this project that already exist. This information was gathered from online sources like the internet, journals an and other relevant materials on the problem domain from libraries around the university.

3.3   Tools

We used notebooks and pens to note down information obtained during the interviews. I addition, we also used smartphones to record the conversations.

Table 3.1: Methods and tools

Method	Tools
Interviews	- Interview guide - Pens and notebooks - Smartphones
Observations	- Personal Computers - Smartphones - Internet
Document Review	- Books - Articles

tabulated below is a summary of the methods used in the data collection process and tools used to implement them.

3.4 Data Analysis

The collected data was analyzed to be able to attain consistency and reliability for proper modeling and implementation of the system. The data was studied to identify key user and system requirements. These were classified under functional and non-functional requirements.

3.5 System Design and Implementation

In order to achieve efficient project management, we adapted the agile software development methodology where the requirements and solutions evolve together throughout the development process. This approach significantly contributed to the success of the project because we were able to anticipate the need for flexibility in time.

3.5.1 System Design

The system was designed using use case and data flow diagrams. The generated use case diagram visually express how the different users interact with the system and the data flow diagrams showed how data flows through the system.

In the development of the use cases, we used the object-oriented analysis development method to design the system. In this phase, we determined the systems requirements and identified the classes and the relationships among the different classes that use the system. There are three major analysis techniques used together during the object oriented analysis namely;

- **bject modeling:** This involves developing the static structure of the software system in terms of objects.

- **Dynamic modeling:** This examines the behavior of the system with respect to time and external changes after the static behavior of the system has been analyzed.

- **Functional modeling:** This shows the processes that are performed within an object and how the data changes as it moves between methods.

3.5.2 System Implementation

The buiding of the system started after having the design complete. this was done by writing code. The tasks were further divided among the different individuals working on the project. Each developer followed a predefined set of guidelines for collaboratin during the development process.

JavaScript and Solidity which is a language used to build smart contracts on the Ethereum platform, are some of the languages used. Another important software in this development is ganache. Ganache is a software that allows one to simulate a blockchain locally on a computer. Ganache has a number of features including displaying the accounts on the local blockchain, the transactions made, the blocks in the network, among others.

Finally, we use MetaMask to run the application on a browser. MetaMask is a google chrome extension that allows one run a blockchain application on google chrome browser.

3.6 Testing and Validation

3.6.1 System Testing

This phase involves the assessment of the system to verify if it works properly and also verify if it satisfies the specified requirements. The system has been

availed to potential users to test it. This enables the team get feedback from the potential users of the system. There are two major approaches to testing of the system used ie;

- **White box testing:** In this technique, we critically studied the source code to find out which unit or chunk of code is behaving inappropriately. This helped in optimizing the code and removing extra lines of code which bring in hidden defects or adding more lines of code to make the application work even better.

- **Black box testing:** in this technique, a tester interacts with the systems user interface by providing inputs and examining outputs without knowing how and where the inputs are worked upon.

3.6.2   Validation

Systems validation is the process of checking that a software system meets specification and it fulfills its intended purpose. To ensure data quality, errors should be detected during input, prior to processing and storage and this will be achieved through validating input transactions and input data. If the system conforms to the specified user requirements, the first release will finally be deployed. With time, the system will be upgraded with more improvements and innovative features; this is because systems without innovative features lose their usability in the long run.

3.7   Conclusion

To realize all this, we had to put into play our project management skills and this called for the need to track our progress using daily Stand Up meetings. This is recorded and shared on google sheets [12].

Chapter 4

System Analysis and Design

This chapter describes the study, analysis and design of the system. It highlights the identified requirements and architectural design of the system.

4.1   Overview of the system

The system designed in this project is aimed at having students transcripts stored and shared on a blockchain network. The storage of transcripts on a blockchain network ensures more security in addition to their storage as hard copy documents. To emphasize security, the transcripts are first hashed into data of fixed size and then stored on a blockchain. The system uses IPFS (InterPlanetary File System)[15] to produce a hash code for a transcript. The resultant hash code is then stored on the Ethereum blockchain.
In order to simulate the blockchain locally, this system uses Ganache which runs a local instance of the Ethereum blockchain on a user computer. To gain access to the network, the user needs a browser extension known as MetaMask. MetaMask is a bridge that allows users to visit the distributed web through their browsers. It allows one to run Ethereum dApps[15] right in one's browser. Addition of each transcript to the blockchain costs a certain amount of ether[16], the currency for the Ethereum blockchain.
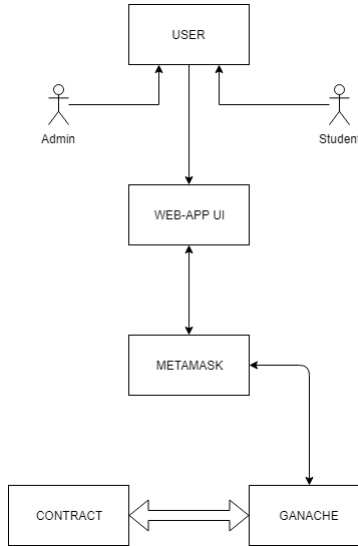
Figure 4.1: Simple system Architecture

4.2 System Analysis

4.2.1 Data Analysis

From the data retrieved during the research process, we found that the present system handling students records is prone to a number of errors and weaknesses.

The current system handling students results at Makerere University does not have a limit to the number of times a student can do a course as opposed to the actual policy by the University where a student is meant to sit for exams in a course not more than three times.

Another discovery from the data received was that the present-day system handling students results at Makerere University can accept an input of a percentage figure greater than 100%.

Another important note is that currently, students' transcripts exist only in hard copy and can only be picked and verified at the University.

4.2.2 System Requirements

The system uses IPFS and the Ethereum blockchain as its main foundation. MetaMask is a browser extension required for user access to the Ethereum blockchain via a browser e.g. Google Chrome, Mozilla Firefox among others. Below are the user requirements, functional and non-functional requirements.

User Requirements

U.1 Allow an administrative assistant enter students results.

U.2 Allow students to access their results without being able to change them.

U.3 Provide for students to easily share their results information with employers.

U.4 Allow employers to easily verify students' results.

Functional Requirements

F.1 Provide verification of a user.

F.2 Ensure that the students results are not altered.

Non Functional Requirements

N.1 The system must verify any addition to the blockchain.

N.2 The system must notify the system administrator incase of any unauthorized transactions.

4.3   System Design

The system is dependant on two technologies i.e IPFS and Ethereum. This section includes an overview of how each of these technologies work.

- **IPFS**
  IPFS is an open-source, peer-to-peer distributed hypermedia protocol that aims to function as a ubiquitous file system for all computing devices. It is a complex and highly ambitious project with some serious and profound implications on the future development and structure of the Internet as we know it.

Figure 4.2: IPFS decentralized architecture.
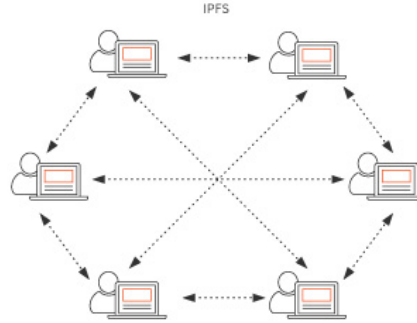
The links between the nodes in IPFS take the form of cryptographic hashes, and this is possible because of its Merkle DAG[18] (Directed Acyclic Graphs) data architecture. Each file and all blocks within it are given a unique identifier, which is a cryptographic hash. Duplicates are removed across the network and version history is tracked for every file.

- **Ethereum blockchain**
  Ethereum's architecture allows for an application to sign transactions offline and relay them to a public node. In this project, since we are running a local instance of the blockchain using Ganache, we have set up a web3 provider engine in our configuraion to transparently sign transactions offline, using Metamask, and send them to an IPFS node.

Figure 4.3: Ethereum blockchain architecture with offline Signing and public nodes.
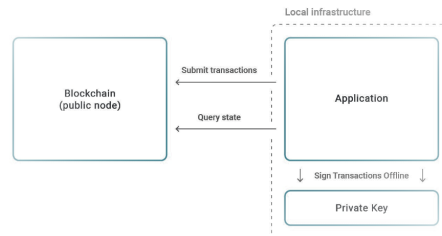
4.3.1 System Architecture

The structure of the system is composed of the following major components:

- A blockchain network built on the Ethereum platform and a local implementation of it running in Ganache.

- The IPFS distributed network for storage and peer-to-peer sharing of records.

- A students' results system that combines:

    1. Creation and Manipulation of results locally
    2. Storage, Access and distribution of results remotely

- A storage server for student information and transcripts

Below is a class diagram describing the structure of the system and a use case diagram depicting the interactions among the system's elements.
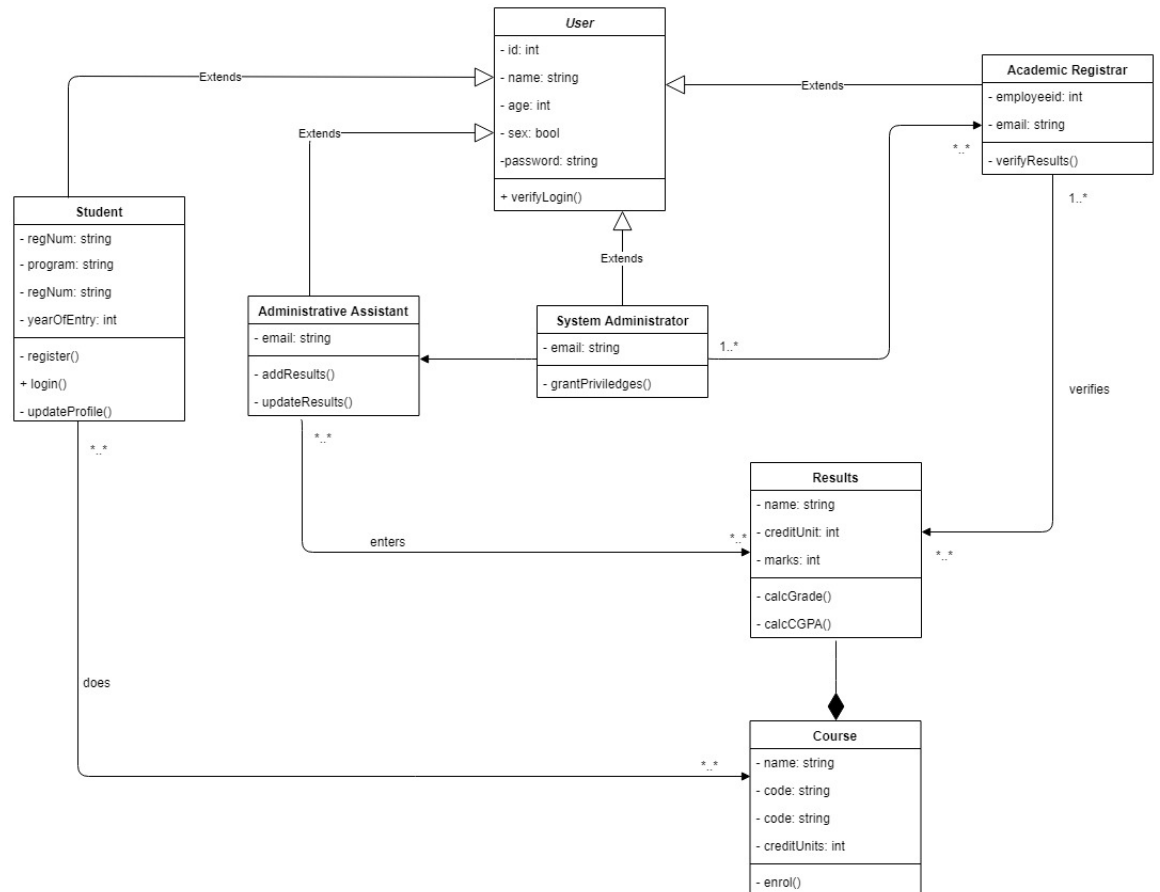
Class Diagram

Figure 4.4: Class diagram

Use Case Diagram
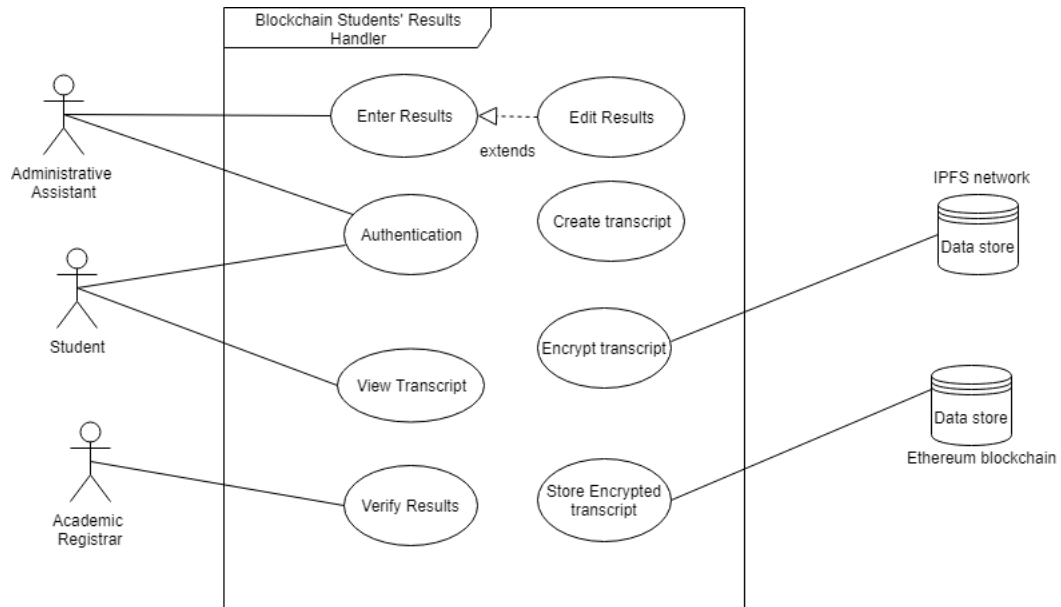

Figure 4.5: Use Case diagram

4.3.2 Design Constraints

Accessing the blockchain network requires reliable internet connectivity.

One needs to have the MetaMask browser extension installed on their browsers in order to access the blockchain network.

Writing to the blockchain costs gas. Gas in the context of Ethereum is a unit and a measurement for the computing power that is needed to execute certain operations in the Ethereum Virtual Machine (EVM).

The developers were limited to only ten virtual accounts to simulate actual accounts during development.

Assumptions

Some assumptions were made during the design and development of the system which include;

The end-user is willing to learn and adopt to the technology that may be new to him/her.

Users always have good internet reception.

Users are familiar with common internet browsers and file extensions for these browsers.

Scalability of the system will not negatively affect the applications speed and reliability.

4.3.3 Design Methodology

We used the Agile software development (ASD) methodology. This methodology involves adaptive planning, evolutionary development, early delivery, and continual improvement. It also encourages rapid and flexible response to change. We focused on keeping code simple and testing often. This helped us to minimize risks such as bugs, cost overruns and the changing requirements.

4.3.4 Graphical User Interface (GUI) Design

This section provides the detailed design of the system and subsystem inputs and outputs relative to the user.

Inputs

Ethereum network password: the users password is required to create an account on the Ethereum network. If the user is logging in on a different device from a previous one that was used to access the network, theyll have to enter the seed phrase generated for them by the platform.

Results: When an administrative assistant logs into the system, he/she can enter the students results.

Outputs

Testimonial: before the results are forwarded to the blockchain, a student can access the system and view his/her progressive results.

Transcript: On accessing the platform, a student can view his transcript which can be printed as a pdf. An employer who would like to view an applicants past results can also access the network and view the same transcript.

4.3.5 External Interfaces

Hardware Interfaces

To fully access the functionality of this system, a user is required to have Computer with an internet browser(like google chrome, mozilla firefox, among others) with the MetaMask browser extension installed.

Software Interfaces

The functionalities of the external interfaces were developed using web-based scripting langauages like PHP, JavaScript and the blockchain network built on the ethereum platform.

Communication Interfaces

The student details handled by the system are stored on an online sql database. The fully processed and verified transcript is stored on the blockchain built on the ethereum platform.

User Interfaces

Users navigate through the application using a windowed GUI. This involves clicking using a mouse, dragging and dropping among other manoeuvres possible with a windowed GUI.

Chapter 5

System Implementation, Testing and Validation

5.1 Introduction

This chapter describes how the Students results handler was implemented. The implementation was driven by the desire to achieve the objectives set at the beginning of the project.

5.2 System Implementation

This section contains an overview of the project implementation; it highlights the major components and the operation of the system as well as the different user interfaces and activities that allow users to interact with the system.

5.2.1 Implementation tools

This application has various faces that can be accessed by the student, the Administrative Assistant, the Academic registrar and a potential employer. Various tools are used to develop these for example, the truffle framework which provides an environment to write smart contracts in solidity and compile them. Other tools include Ganache[14] which is a blockchain network simulator on a local machine.

The front end of the application is developed in languages such as JavaScript, HTML and using the bootstrap framework as well.

5.2.2 User Interface Design

The system can be accessed through a web application on a browser of choice. However, the browser should be able to support the MetaMask file extension.

This is helpful in enabling the user access the blockchain network.

Account Creation

For a student still on normal academic progress, he/she has the ability to register and have an account. This requires the student id number and a password.

However, for access to the blockchain, the student or any other user intending to access the verified transcript has to create an account on the Ethereum[13] network. During this process, a seed phrase is automatically generated for a user and he/she only has to create a password.
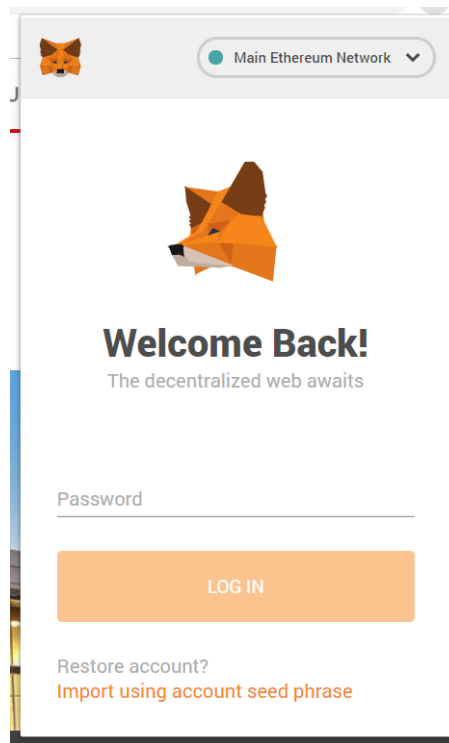

Figure 5.1: Loging into the ethereum network

Results

Viewing Results

This page can be accessed by a logged in student or an administrative assistant. The student can only view his/her results whereas the administrative assistant can view the results of various students. **Manipulating results**

In addtion to viewing results of various students, the adminsstrative assistant can also add/edit students results.

Chapter 6

Recommendations, Conclusion and Future Works

Chapter 7

Appendices

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