A BLOCKCHAIN APPLICATION FOR THE VERIFICATION OF ACADEMIC INFORMATION AND SCALABLE CERTIFICATION

Submitted in partial fulfillment of the requirements for the award of a Bachelor of
Engineering degree in Computer Science and Engineering

By

MULAGAPAKA ASHISH (Reg.No - 39110650)
CHEEPURUPALLI DURGA PRADEEP(Reg.No – 39110217)

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

SCHOOL OF COMPUTING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with Grade "A" by NAAC
JEPPIAAR NAGAR, RAJIV GANDHISALAI,
CHENNAI - 600119

APRIL 2023

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with –A|| grade by NAAC

Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119

www.sathyabama.ac.in

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **MULAGAPAKA ASHISH(39110650) and CHEEPURUPALLI DURGA PRADEEP(39110217)** who carried out Project Phase-2 entitled **"A BLOCKCHAIN APPLICATION FOR THE VERIFICATION OF ACADEMIC INFORMATION AND SCALABLE CERTIFICATION"** under my supervision from January 2023 to April 2023.

Internal Guide

Ms. R. YOGITHA M.E., (Ph.D)

Head of the Department

Dr. L. LAKSHMANAN, M.E., Ph.D.

Submitted for Viva-voce Examination held on 20.04.2023

Internal Examiner **External Examiner**

DECLARATION

I, **MULAGAPAKA ASHISH(Reg. No- 39110650),** hereby declare that the Project Phase-2 Report entitled **"A BLOCKCHAIN APPLICATION FOR VERIFICATION OF ACADEMIC INFORMATION AND SCALABLE CERTIFICATION"** done by me under the guidance of **Ms. R. YOGITHA M.E., (Ph.D.)** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in **Computer Science and Engineering**.

DATE: 20.04.2023

PLACE: Chennai

MULAGAPAKA ASHISH

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to the **Board of Management** of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. T.Sasikala M.E., Ph. D**, **Dean**, School of Computing, and **Dr. L. Lakshmanan M.E., Ph.D.,** Head of the Department of Computer Science and Engineering for providing me with the necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Ms. R. YOGITHA M.E., (Ph.D.)** for her valuable guidance, suggestions, and constant encouragement that paved way for the successful completion of my phase-2 project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the **Department of Computer Science and Engineering** who were helpful in many ways for the completion of the project.

ABSTRACT

In recent years, blockchain technologies have piqued the interest of a variety of actors across several industries, including the education sector, which is researching how to use them to improve information traceability, accountability, and integrity while ensuring its privacy, transparency, robustness, trustworthiness, and authenticity. Several intriguing projects and proposals have been started and are still being developed. This study examines the issues associated with using blockchain technology to create and validate educational data and suggests a creative method to address them. The suggested model conforms with existing laws, safeguards the privacy of users' data, and supports the issuance, storage, and verification of various types of academic material, both official and informal. This idea clears the way for an international academic certification system while addressing the scalability difficulties. Hence, use Blockchain technology to verify Academic Information which is highly scalable guaranteeing the privacy of users’ data. This is helpful to the employer to verify the academic information about the employee.

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Currently, each educational institution's proprietary systems are used to issue and register academic data, which keeps it mostly separate from other organizations' record-keeping practices. This condition directly influences the verification of students' academic records because, in many situations, a transcript or certificate may only be authenticated manually, which is exceedingly time- and resource-intensive. In an environment where competition is on the rise, there is a growing need to demonstrate acquired abilities and competencies, that come from five different sources:

(1) False credentials produced by "degree mills" and sold to consumers who pay for them.

(2) Falsified academic records produced by nonexistent institutions.

(3) Changed documents that add fake dates, courses, specialties, etc. to real documents.

(4) "In-house" certificates are false academic documents that are printed, sealed, and produced by a legitimate school but were made by dishonest staff.

(5) Erroneous translations of official papers that are used to fulfill obligations in a foreign country and a language other than their own.

As a result, in an increasingly connected society, the prevalence of phony academic credentials and accreditations poses a serious issue that needs to be addressed and resolved. However, there are neither centralized record-keeping systems for these kinds of records nor widely agreed standards for academic information representation. The traceability between graduates and their original completed studies will also be lost if a currently operational institution discontinues its educational activities and disappears, which in turn inhibits the verification of such studies by a third party. These problems may be resolved by a reliable blockchain-based system, which makes it possible for third parties to simply verify registered user and academic information without fear of tampering. To record all relevant educational data, it must be scalable and effective. It must also preserve the privacy of every piece of personal information and adhere to all applicable laws.

This proposed model makes use of blockchain technology, which is ideal for achieving the sought-after goals due to its characteristics of resistance to unauthorized modifications and traceability of the carried-out operations, to propose creative solutions for issuing, storing, recovering, and verifying heterogeneous types of academic information. It is also crucial to note that, as will be mentioned later, the current blockchain-based rate and validates academic data uses a variety of methods to capture the data. Before the invention of blockchain, there were numerous data integrity, scalability, availability, and security issues. Blockchain effectively addressed those issues. A distributed, peer-to-peer database called a blockchain house an ever-increasing volume of transactions. A "block" is a collection of related transactions that are each encrypted, timestamped, and verified by all authorized database users using consensus techniques.

Fig. 1. Block Chain

Before becoming fully incorporated into society, blockchain will have to overcome a variety of adoption hurdles. Scalability, the time required to authenticate transactions, transaction costs, and security are a few of them. Blockchain is decentralized since none of its data is kept in one place. Instead, a network of computers copies and disseminates the blockchain. Every computer in the network updates its blockchain whenever a new block is added to the blockchain.

.

Ethereum is a blockchain platform that has its programming language, Solidity, and cryptocurrency, called Ether (ETH) or Ethereum. Ethereum is a decentralized public ledger for confirming and storing transactions since it is a blockchain network.

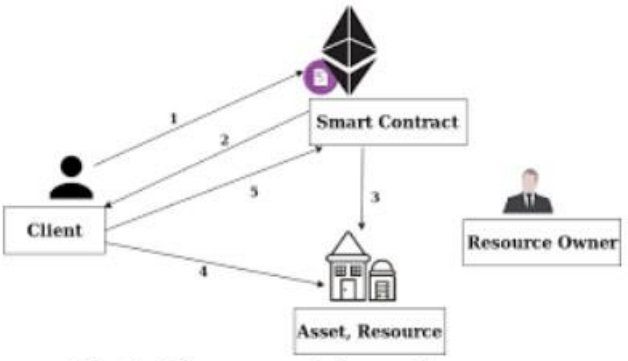

Fig. 2. Ethereum and Smart Contracts

As a result, in an increasingly connected society, the prevalence of phony academic credentials and accreditations poses a serious issue that needs to be addressed and resolved. However, there are neither centralized record-keeping systems for these kinds of records nor widely agreed standards for academic information representation. The traceability between graduates and their original completed studies will also be lost if a currently operational institution discontinues its educational activities and disappears, which in turn inhibits the verification of such studies by a third party.

Additionally, without a globally accessible platform for academic information, it is impossible to compare how students from other nations get their degrees or to get a general understanding of what kinds of formal or even informal studies are most in demand.

These problems may be resolved by a reliable blockchain-based system, which can tamperproof register academic information for simple third-party verification. To record all relevant educational data, it must be scalable and effective. It must also preserve the privacy of every piece of personal information and adhere to all applicable

CHAPTER 2

LITERATURE SURVEY

The work of Join-Chiou subgenus Chen, Narn-Yih Lee, Chien Chi, and Yi-Hua subgenus Chen “Blockchain and sensible Contract for Digital Certificate” [1] The digital certificate system enabled by blockchain technology would be planned to address the issue of certificate forging. A digital certificate with anti-counterfeit and verifiability may be made possible by blockchain's immutable characteristics. In this system, the process for issuing digital certificates is as follows. First, an electronic file for a paper certificate that is associated with another piece of connected knowledge is created. This is followed by calculating the hash value of the electronic file.
Finally, the hash price is kept in the block within the chain system. A QR code and inquiry string code associated with the certificate are generated by the system to affix to the paper certificate. a requirement unit is provided to verify the believability of the paper certificate by scanning through mobile phones or by website inquiries. thanks to the unmodifiable properties of the blockchain, the system enhances the believability of assorted paper-based certificates and conjointly electronically minimizes the loss risks of assorted forms of certificates.

Austin trader, Aryan Familrouhani, Devin Cao, Tevisophea Heng, Wenlin Han dynasty “Security Applications and Challenges in Blockchain” [2] Blockchain technology, which is used today and has long-term implications, is immensely widespread but is still a very misunderstood concept. Several applications use Blockchain to increase protection and privacy. However, there are inherent problems with units and growing difficulties. In this paper, we examine the most prevalent security applications in blockchain, their main problems, as well as other obstacles in blockchain that enable future research to be carried out much more effectively.

Marco Baldi, dictator Chiaraluce, Emanuele Frontoni, Giuseppe Gottardi, Daniele Sciarroni and Luca Spalazzi Certificate "Validation through Public Ledgers and Blockchain" [3] For the continued existence of online services relying on certificate-based authentication, such as e-commerce, e-government, trade sector, online banking, as well as email, social networking, cloud services, and many others, public key infrastructures (PKIs) are essential. The security and dependability of certificate revocation lists, which must be available and authentic whenever a certificate is used, are one of the most common points of failure of modern PKIs (public key infrastructures).

Traditionally, the certification authority (CA) that issued a group of certificates would retain the CRL for that collection, introducing one POF into the system. We propose a solution to this problem that would allow many CAs to share a strong, public ledger wherever CRLs are gathered. For this, we tend to consider the blockchain-based public ledger architecture that was created for use with cryptocurrencies and is now a popular option for many web applications with stringent security and dependability requirements.

Santosh Pandey, Gopal Ojha, Rohit Kumar, and Bikesh Shresha "BlockSIM: A sensible simulation tool for optimum network style, stability, and planning" [4] In this work, they need to introduce a BlockSIM, which is a

comprehensive and open-source tool for simulating blockchain systems. Simulating scenarios and selecting the simplest or most advantageous system parameters appropriate to their roles, it will assist blockchain architects in conducting better analyses of the performance of planned private blockchain networks. To ensure that scalable, extendable, stable, and robust blockchain networks are designed and implemented, blockchain system architects must take note of the similarities and contrasts between the simulation's results and the $64,000 blockchain networks. Additionally, a real-world example is given to show how the architects would use BlockSIM to plan and design blockchain systems in the real world.

Christopher Ehmke, Florian Wessling, and Christoph M. Friedrich "Proof-of-Property - a light-weight and scalable Blockchain Protocol" [5 The strategy outlined in this paper is based on Ethereum's idea that the system state should only exist in the current block, but it furthers this idea by including the pertinent portions of this system state in new transactions. This avoids the need to transfer the complete blockchain at first and enables different participants to see incoming transactions. Following these ideas, use cases that require scalable blockchain technology but do not necessarily require an Associate in Nursing endless and comprehensive group activity history will be enabled.

S. Sunitha Kumar, D. Saveetha "Blockchain, and sensible Contract for Digital

Document Verification" [6] In the intended system, along with the degree certificate, the user's full temperament and history of behavior are uploaded to the blockchain. Due to its immutable nature, it is stored in the blockchain. The coed can first submit a certificate or personal identification to an electronic certificate system to request the e-certificate. Once the system receives the request for an e-certificate, it can analyze the certificate provided by a university, faculty, or organization, obtain the assurance, and deposit the serial number and e-certificate on the blockchain. The QR code can be created by the system and sent to the user. After applying for a job, a user only needs to provide the QR code and certificate serial number they received from the electronic certificate system.

Arvind Ramachandran, and Dr. Murat Kantarcioglu "Using Blockchain and sensible contracts for secure knowledge cradle management" [7] use blockchain as a platform in this endeavor to create reliable knowledge cradle selection, verification, and management. The created system effectively records changeless knowledge trails through the use of smart contracts and the open cradle model (OPM). The study demonstrates that provided a majority of participants are truthful, the proposed architecture will effectively and firmly capture, check or validate cradle knowledge, and prevent any malicious alterations to the captured knowledge.

Ahmed ben Ayed "Secure storage service of electronic ballot system supported blockchain algorithm" [8] In this essay, the writers use the free and open-source Blockchain technology to develop a new idea for an electronic judicial system that would be used in local or national elections. The blockchain-based system is secure, trustworthy, and untraceable, and it

can help raise voter turnout as well as public confidence in governments.

Kaidong wu "An Empirical Study of Blockchain-based localized Applications" [9] This research presents a thorough empirical investigation of a detailed dataset of 734 distributed applications (dapps) that was gathered from three well-known open localized application markets, namely Ethereum, State of the Dapp, and DAppRadar. We prefer to examine the identification of dapps and present the ephemeral patterns of how rational contracts are structured within a dapp. We tend to draw some conclusions from the results to help dapp developers and consumers better understand and deploy dapps.

Jialiang chang, Bo Gao, Hao Xiao, Jun Sun, and Zijiang' s principle "compile: crucial Path Identification and Analysis for sensible Contracts" [10] is Another method to automatically identify critical program methods (with multiple perform calls as well as inter-contract perform calls) during a sensible contract, rank the methods according to their criticality, discard them if they are impractical, or otherwise provide them with user-friendly warnings for user examination has been planned. Methods that entail financial group activity have been identified as critical methods, and those that undoubtedly violate crucial features have been given priority. Symbolic execution techniques are only used for high hierarchical important methods to be quantifiable. This strategy has been used in 36,099 reasonable contracts that have been processed using a tool called Compile. The

experiment's findings demonstrate that Compile is efficient; on average, one decent contract takes five seconds to create.

2.1 INFERENCES FROM LITERATURE SURVEY

It is evident from the cited literature works that this subject has been thoroughly researched and that numerous models have been put forth. Each of the aforementioned methods has advantages and disadvantages. Even while several recent works use hybrid methods and offer greater accuracy, they are still far from being sufficient. Higher accuracy necessitates lower computing costs, faster processing speeds, and most importantly, ease of use.

2.2 OPEN PROBLEMS IN THE EXISTING SYSTEM

The current system does not operate in real time and is also inaccurate and inefficient in terms of loading and implementation times. The current technique only examines a small portion of the certificate's information and is unable to detect similarities between certificates.

CHAPTER 3

REQUIREMENT ANALYSIS

3.1 FEASIBILITY STUDIES/RISK ANALYSIS OF THE PROJECT

In this stage, the project's viability is determined by the increase in server performance, and a business proposal is presented with a very basic project design and some cost projections. The feasibility assessment of the suggested system must be completed during system analysis. Understanding the main system requirements is crucial for the feasibility analysis.

Three key considerations involved in the feasibility analysis are

- Economical feasibility
- Technical feasibility
- Operational feasibility

ECONOMICAL FEASIBILITY

This study is being done to see what kind of financial impact the system will have on the company. The corporation has a finite amount of money to invest in the system's research and development. The costs must be supported by evidence. As a result, the developed system came in under budget, which was made possible by the fact that most of the technology was public domain. Only the specialized goods needed to be bought.

TECHNICAL FEASIBILITY

This study is being done to evaluate the system's technical requirements or technical feasibility. Any system created must not place a heavy burden on the technical resources at hand. As a result, the client will face high expectations. The created system must have reasonable requirements because its implementation only necessitates minor or no adjustments.

OPERATIONAL FEASIBILITY

The goal of the study is to determine how much the user accepts the system. This includes the instruction needed for the user to operate the system effectively. The system shouldn't make the user feel threatened; instead, they should view it as a need. The techniques used to inform and acquaint the user with the system are the only factors that affect the level of acceptance by the users. He has to have more self-assurance because he will be the system's last user and will be able to offer some helpful critiques.

3.2 SOFTWARE REQUIREMENTS SPECIFICATION DOCUMENT

Hardware specifications:

- Microsoft Server enabled computers, preferably workstations
- Higher RAM, of about 4GB or above
- The processor of frequency 1.5GHz or above
    - Processor of frequency 1.5GHz or above

Software specifications:

Ganache – Creates a Local Ethereum test environment.

Truffle – Initialise basic setup for Ethereum Dapp

React js – for frontend implementation

Web3.js	–	for interacting with Smart Contracts
IPFS	–	for decentralized file storage
Meta Mask	–	Wallet for connecting with Ethereum Network
Vscode	–	code editor

CHAPTER 4

DESCRIPTION OF THE PROPOSED SYSTEM

4.1 SELECTED METHODOLOGY OR PROCESS MODEL

Each university will provide its students with certificates that are uniquely identified by the student's Metamask wallet address. The push for this Certificate will be the network with the Merklee hash value, IPFS value, accessed by, and certificate id as arguments.

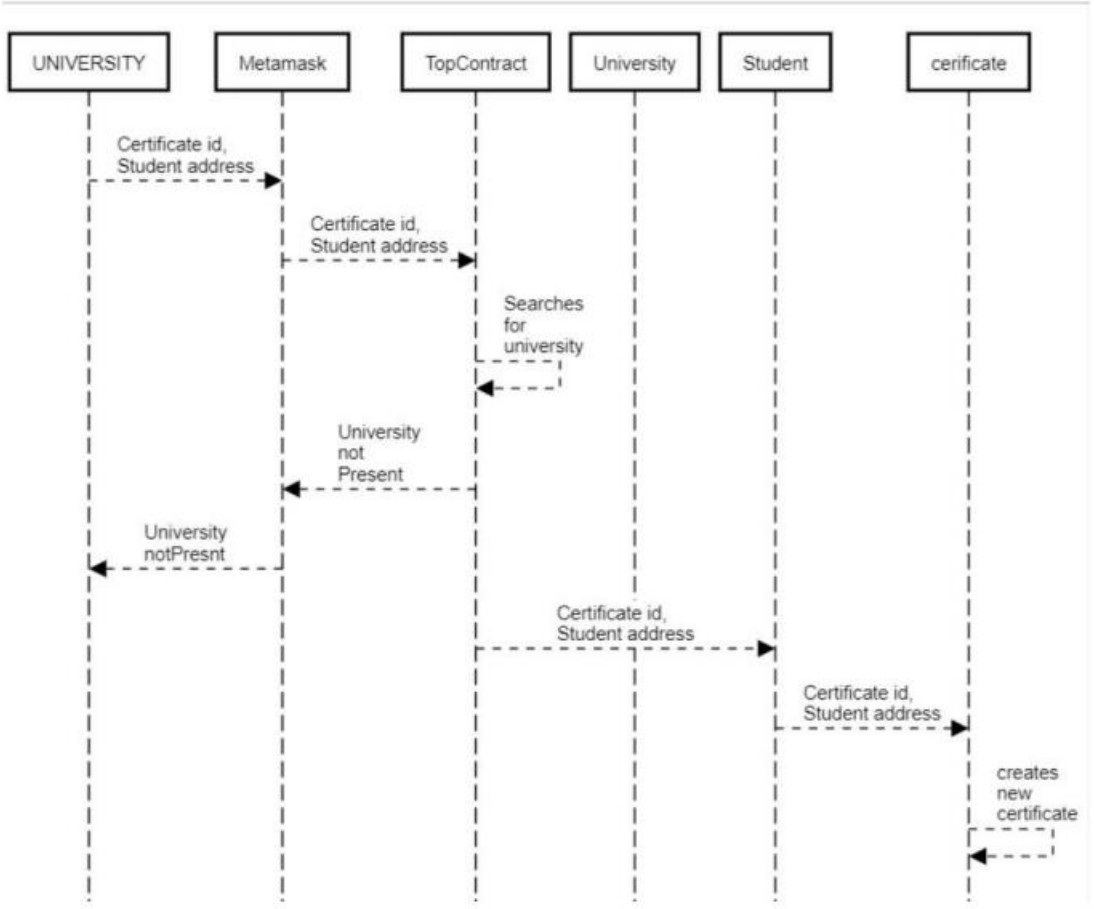

Fig 4.1.1 Add Certificate Diagram

Additionally, each student has the option to request a certificate from their university, after which the institution will either provide the requested certificate or refuse it. The learner can download the certificate from the blockchain if access is granted (IPFS).

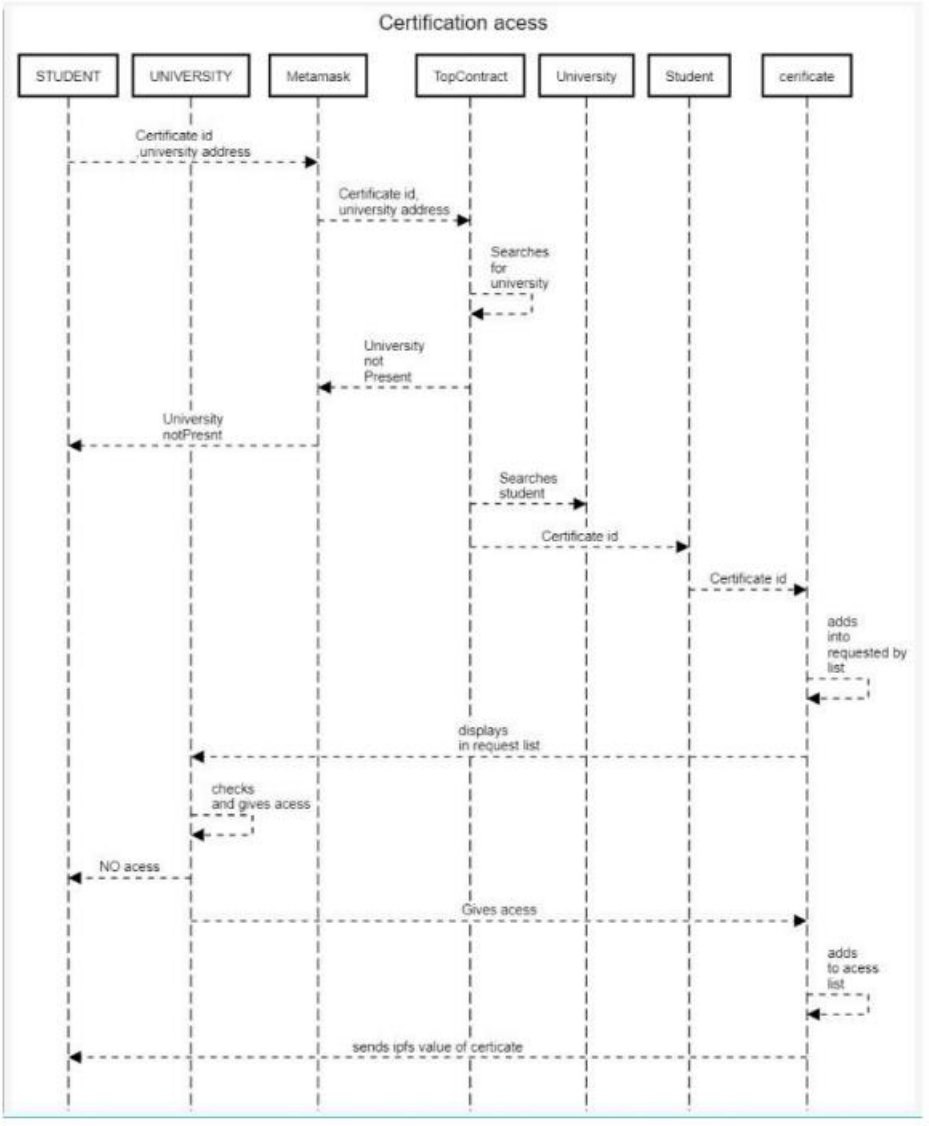

Fig 4.1.2 Certificate Access Diagram

Each company has the opportunity to publish a job with specific employment information, such as the job kind, pay scale, and location. The provider will push this information to the network, saving all the data and creating new variables like who has applied for a job and who hasn't been validated yet.

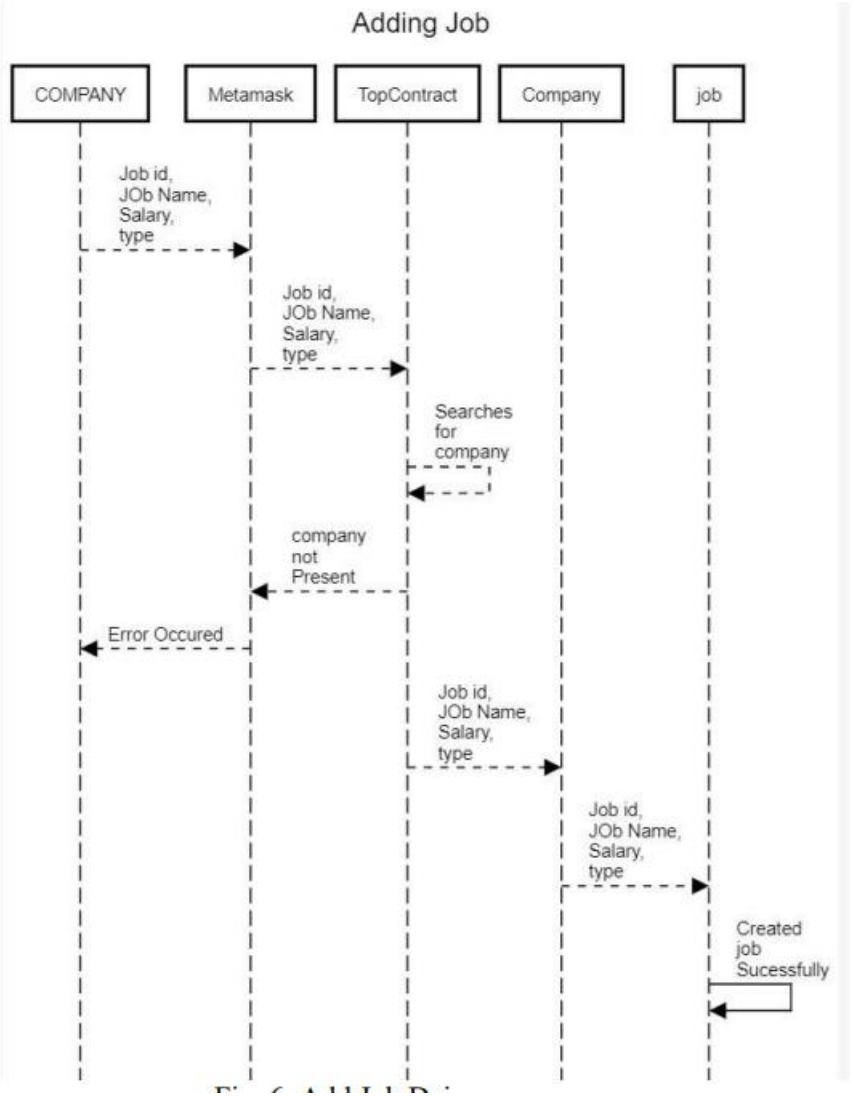

Fig. 4.1.3 Add Job Diagram

Every student has the opportunity to apply for any job that has been listed by a different company, but they must do so by using their certificate number when doing so. The address of the student who applied will be added to the list of applicants in the smart contract for the job. The firm then can verify the certificates, which use ipfs values and Merklee hash values to check. This will update the applied individuals on the corporate side.

The company has two choices if the certificate is verified: it can reject the application or hire the candidate. Every corporate decision is communicated to the student side.

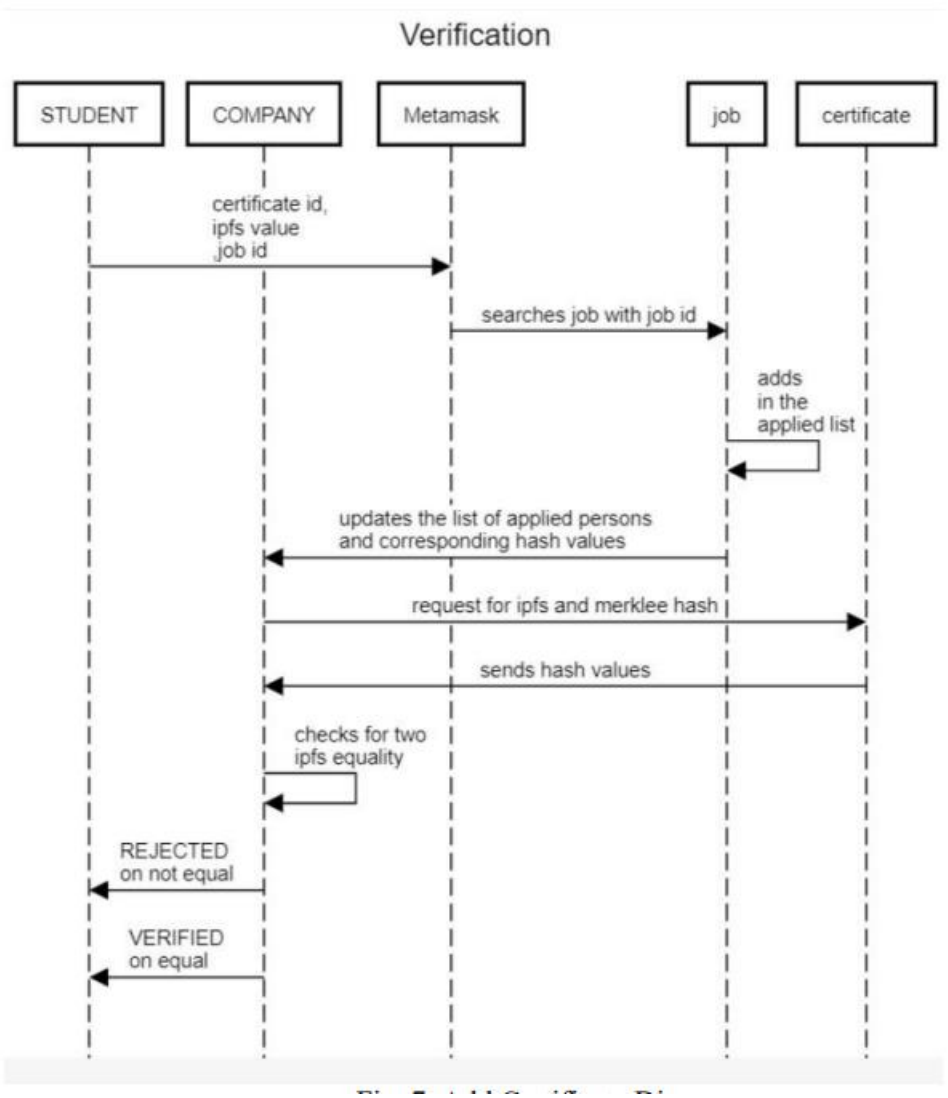

Fig. 4.1.4 Add Certificate Diagram

4.2 ARCHITECTURE / OVERALL DESIGN OF THE PROPOSED SYSTEM

The preceding section's discussion of prior initiatives, their limits, and downsides, as well as the examination of the state of the art of blockchain technology in education, shed some light on the desired characteristics of creative solutions solving the stated problems.

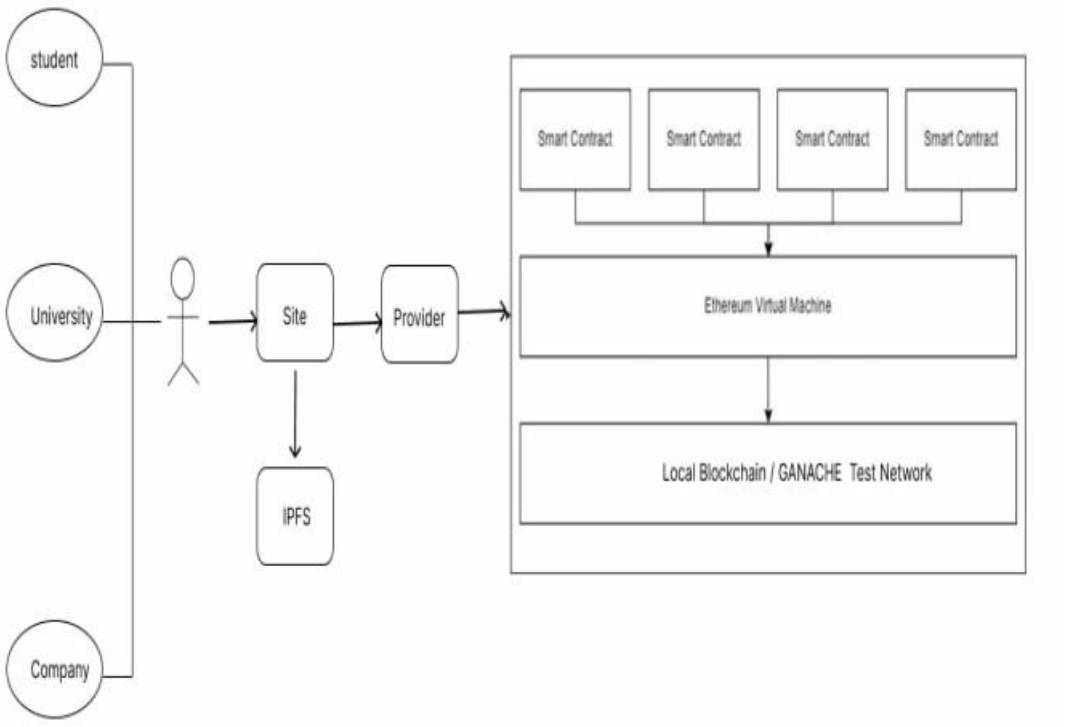

Fig. 4.2.1 Architecture

4.3 DESCRIPTION OF SOFTWARE FOR IMPLEMENTATION AND TESTING PLAN OF THE PROPOSED MODEL/SYSTEM

The Truffle Suite's use of the Ganache smart contract development platform is a prime example of simplicity. Ganache installation doesn't require that you go through any difficult stages. Search the Truffle Suite website for the "Download" button for Ganache. As soon as you click the Download button, the download will begin. The local blockchain must be configured after the program has been downloaded by selecting the "QUICKSTART" button on the Ganache UI. Make sure you have the right file format downloaded for your operating system. These Ganache file versions work well on various operating systems.

- Linux: Ganache-*.App Image
- Windows: Ganache-*.appx
- Mac: Ganache-*.dmg

By double-clicking the downloaded file, you can launch the installation of the Ganache Solidity blockchain testing network. You may easily complete the installation procedure and start using Ganache by following the onscreen instructions. It's also crucial to

remember that you have to confirm your decision to let Google Analytics track you. The development team can benefit from a wealth of insightful data on the use of Ganache thanks to the optional facility for Google Analytics tracking. Most importantly, Google Analytics tracking is fully anonymous because no private keys or account information are ever shared.

The logical next step after downloading and installing Ganache is to set up a workspace. You may find the home screen when you first launch Ganache and begin utilizing the Ganache blockchain for testing from there. You would be prompted to load any already-existing workspace or to build a brand-new, unique workspace. On the other hand, adopting the default settings allows you to immediately begin a one-click blockchain. The quickstart workspace option enables one-click blockchain creation. The best way to launch your workspace is to choose the Corda or Ethereum networks from the QUICKSTART drop-down menu. Simply press the QUICKSTART button one more to start setting up your workplaces.

To simplify the work of developers, Truffle is a top-notch programming environment, testing framework, and asset pipeline for blockchains running on the Ethereum Virtual Machine (EVM).

With over 1.5 million lifetime downloads, Truffle is regarded as the most well-liked tool for developing blockchain applications. Whether they choose to build on Ethereum, Hyperledger, Quorum, or one of the ever-expanding list of additional supported platforms, Truffle enables developers throughout the whole lifecycle of their projects. The entire Truffle toolkit aims to be an end-to-end dApp development platform when combined with Ganache, a personal blockchain, and Drizzle, a front-end dApp development kit.

Two pre-configured Truffle boxes are pre-installed in Kaleido setups to make it simple to build and deploy a simple decentralized application. Truffle is a particularly beneficial development framework because it enables quick, lightweight testing and iteration while abstracting many of the web3 and Ethereum complications that are often present in the creation of blockchain apps. Without having to have a lot of experience with client libraries and JSON/RPC APIs, this is a fantastic way to get started.

The simple storage smart contract is created and instantiated by the first box, the truffle-Kaleido box. Simple storage updates the state using only one method, set, and one global variable, stored data, which is an unsigned integer.

How to install React App

We must first open our computer's terminal or command line before we can use Create React App. If you have an npm version of at least 5.2, you can use the tool npx to start a new React project. It is quite useful because npx allows us to utilize the create-react-app package without first having to install it on our machine.
Utilizing npx guarantees that we will be using the most recent version of Create React App when we finish our project:

npx create-react-app my-react-app

A folder called "my-react-app" will be created where we indicated on our computer when we run this command, and all of the packages it needs will be installed automatically.

Additionally, Create React App provides us with certain templates for various React project kinds. For instance, rather than having to manually install TypeScript, we could use a template to create a React project that uses the TypeScript tool. We can use the Create React App TypeScript template to build a React app that utilizes TypeScript:

npx create-react-app my-react-app --template typescript

Reviewing the project structure

my-react-app
├── README.md
├── node_modules
├── package.json
├── .gitignore
├── public
└── src
How to Run React Project

Open your terminal by selecting View > Terminal in VSCode once you have dragged your project into your code editor.

Run the following command to launch your React project:

```
npm start
```

ConsenSys developed MetaMask, which is currently the most widely used Ethereum-compatible wallet. With a safe browser extension that works with Chrome, Firefox, Brave, and Edge, you may access it. Recently, ConsenSys introduced a financial integration that enables qualified users to send money directly from their bank account to their wallet.

Avalanche, Polygon, Binance Smart Chain, Fantom, Harmony, and other blockchains are all fully compatible with MetaMask, even though it is most frequently used for Ethereum network transactions. For instance, your MetaMask wallet will allow you to store NFT wearables and other stuff for your avatar in Decentraland. To use them, though, you'll need to have your wallet connected to the app.

Installing the Extension

Start by going to MetaMask. Once there, you'll notice a blue download button for the extension for your chosen browser.
Simply click that icon to be directed to the Chrome Web Store. On this website, you may read reviews and find out more information about the program. When you're ready to go, click the Add To Chrome button, and your free MetaMask wallet will install.
When MetaMask has successfully been installed, a notification will show up and the small fox icon will appear in the upper right corner of your screen.

Setting up Your Metamask Wallet

If you're a new user, create a new wallet by clicking the "Create a Wallet" button on the right. You will then be prompted by the system to decide if you want to share analytics with MetaMask. You are in complete control of this choice. You'll then be asked to create a password.

This is the password you need to access your local device's wallet. You should be sure to use a strong password with this account as well as any other online account. You'll be given a list of 12 words that serve as your private key on the following page. Once you've entered those words, you can click "Continue." Then, you're done!

REFERENCES:-

1. Saleh, O.S.; Ghazali, O.; Rana, M.E. Blockchain-based framework for educational certificates verification. *J. Crit. Rev.* **2020**, *7*, 79–84. [**Google Scholar**] [**CrossRef**]
2. Muzammil, M. Corrupt schools, corrupt universities: What can be done? *Comp. A J. Comp. Int. Educ.* **2010**, *40*, 385–387. [**Google Scholar**] [**CrossRef**]
3. Creating Pathways to Careers in IT. Available online: **https://services.google.com/fh/files/misc/it_cert_impactreport_booklet_rgb_digital_version.pdf.** (accessed on 16 March 2021).
4. Lyons, T.; Courcelles, L.; Timsit, K. *Blockchain and the GDPR*; The European Union Blockchain Observatory and Forum, European Commission: Brussels, Belgium, 2018. [**Google Scholar**]
5. Nakamoto, S. Bitcoin: A Peer-to-Peer Electronic Cash System. 2008. Available online: **https://www.bitcoin.org/bitcoin.pdf.** (accessed on 17 January 2021).
6. Andoni, M.; Robu, V.; Flynn, D.; Abram, S.; Geach, D.; Jenkins, D.; McCallum, P.; Peacock, A. Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renew. Sustain. Energy Rev.* **2019**, *100*, 143–174. [**Google Scholar**] [**CrossRef**]
7. Mirabelli, G.; Solina, V. Blockchain and agricultural supply chains traceability: Research trends and future challenges. *Procedia Manuf.* **2020**, *42*, 414–421. [**Google Scholar**] [**CrossRef**]
8. Khezr, S.; Moniruzzaman, M.; Yassine, A.; Benlamri, R. Blockchain Technology in Healthcare: A Comprehensive Review and Directions for Future Research. *Appl. Sci.* **2019**, *9*, 1736. [**Google Scholar**] [**CrossRef**][**Green Version**]
9. Jiang, S.; Cao, J.; Wu, H.; Yang, Y.; Ma, M.; He, J. BlocHIE: A BLOCkchain-Based Platform for Healthcare Information Exchange. In Proceedings of the 2018 IEEE International Conference on Smart Computing (SMARTCOMP), Taormina, Sicily, Italy, 18–20 June 2018; Institute of Electrical and Electronics Engineers (IEEE): Piscataway, NJ, USA, 2018; pp. 49–56. [**Google Scholar**] [**CrossRef**]
10. Pournader, M.; Shi, Y.; Seuring, S.; Koh, S.L. Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. *Int. J. Prod. Res.* **2019**, *58*, 2063–2081. [**Google Scholar**] [**CrossRef**]
11. Conoscenti, M.; Vetro, A.; de Martin, J.C. Blockchain for the Internet of Things: A systematic literature review. In Proceedings of the 2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA), Agadir, Morocco, 29 November–2 December

2016; Institute of Electrical and Electronics Engineers (IEEE): Piscataway, NJ, USA, 2016; pp. 1–6. [**Google Scholar**] [**CrossRef**][**Green Version**]

12. Jiang, S.; Cao, J.; Wu, H.; Yang, Y. Fairness-based Packing of Industrial IoT Data in Permissioned Blockchains. *IEEE Trans. Ind. Inform.* **2020**, 1. [**Google Scholar**] [**CrossRef**]
13. Konstantinidis, I.; Siaminos, G.; Timplalexis, C.; Zervas, P.; Peristeras, V.; Decker, S. *Blockchain for Business Applications: A Systematic Literature Review*; Abramowicz, W., Paschke, A., Eds.; Springer International Publishing: Cham, Switzerland, 2018; Volume 320, pp. 384–399. [**Google Scholar**]
14. Butijn, B.-J.; Tamburri, D.A.; Heuvel, W.-J.V.D. Blockchains. *ACM Comput. Surv.* **2020**, *53*, 1–37. [**Google Scholar**] [**CrossRef**]
15. Casino, F.; Dasaklis, T.K.; Patsakis, C.F. A systematic literature review of blockchain-based applications: Current status, classification and open issues. In *Telematics and Informatics*; Elsevier Ltd: Amsterdam, The Netherlands, 2019; Volume 36, pp. 55–81. [**Google Scholar**] [**CrossRef**]