Decentralizing University Finances: A Blockchain Based Hybrid Solution for Transparent Account Management

Tanvir Ahmed Khan

A Thesis in the Partial Fulfillment of the Requirements

for the Award of Bachelor of Computer Science and Engineering (BCSE)

Department of Computer Science and Engineering
College of Engineering and Technology
IUBAT – International University of Business Agriculture and Technology

Spring 2024

Decentralizing University Finances: A Blockchain Based Hybrid Solution for Transparent Account Management

Tanvir Ahmed Khan

A Thesis in the Partial Fulfillment of the Requirements for the Award of Bachelor of Computer Science and Engineering (BCSE)

The thesis has been examined and approved,

_____

Prof. Dr. Utpal Kanti Das
Chairman and Professor

_____

Shahinur Alam
Senior Lecturer & Coordinator

_____

Dr. Muhammad Hasibur Rashid Chayon
Supervisor and Associate Professor

Department of Computer Science and Engineering
College of Engineering and Technology
IUBAT – International University of Business Agriculture and Technology

Spring 2024

Letter of Transmittal

10 Jan 2023

The Chairman

Thesis Defense Committee

Department of Computer Science and Engineering

IUBAT–International University of Business Agriculture and Technology

4 Embankment Drive Road, Sector 10, Uttara Model Town

Dhaka 1230, Bangladesh

Subject: Letter of Transmittal.

Dear Sir,

With due respect, I would like to inform you that it is a great pleasure for me to submit this report entitled "**Decentralizing University Finances: A Blockchain Based Hybrid Solution for Transparent Account Management**" to complete my thesis course. It was a great opportunity for me to work on this study to make my theoretical knowledge more realistic and I've gained a lot of exposure doing deep research on Blockchain. I now look forward to your kind commentary on this performance report. I will always be very grateful to you if you kindly go through this report and check my performance.

Yours sincerely,

_____

Author: Tanvir Ahmed Khan
Student ID: 20203036

Student's Declaration

I, Tanvir Ahmed Khan, hereby declare that I am the sole author of this thesis entitled "Decentralizing University Finances: A Blockchain Based Hybrid Solution for Transparent Account Management" This thesis is the culmination of my independent work undertaken for the fulfillment of the requirements of the Bachelor of Computer Science and Engineering degree, specifically the CSC 488 Thesis course. The contents of this thesis reflect my original ideas, research, and conclusions. No part of this work has been submitted for any other degree, diploma, or certification. All sources used are duly acknowledged and cited within the text.

_____

Author: Tanvir Ahmed Khan

Student ID: 20203036

Supervisor's Certification

This certifies that the Thesis report titled "Decentralizing University Finances: A Blockchain Based Hybrid Solution for Transparent Account Management" has been compiled by Tanvir Ahmed Khan, bearing ID #20203036, enrolled at IUBAT – International University of Business Agriculture and Technology, as a fundamental part of fulfilling the requirements for the completion of the thesis course. I have overseen and supervised the preparation of this report, and it stands as a comprehensive record of their accomplished work. To the best of my knowledge and based on their declaration, no sections of this report have been utilized for any other academic degree, diploma, or certification. I hereby grant permission for the submission of this report, wishing Tanvir Ahmed Khan success in their future academic and professional pursuits.

Thesis Supervisor,

_____

Dr Muhammad Hasibur Rashid Chayon
Supervisor and Associate Professor
Department of Computer Science and Engineering
IUBAT–International University of Business Agriculture and Technology

Abstract

Blockchain technology, celebrated for its transformative potential, takes center stage in revolutionizing the University Accounts Management System (UAMS). The current framework, entrenched in the vulnerabilities of WEB2.0, necessitates a paradigm shift towards the secure and transparent capabilities of WEB3.0. This proposal outlines the meticulous implementation of a blockchain-powered UAMS, leveraging the robust SHA256 encryption algorithm. By integrating blockchain, the system fortifies transactional security, minimizes data errors through pre-checking mechanisms, and significantly reduces the cost of storing extensive data, thanks to the integration of IPFS Pinata. The adaptability of the framework ensures a seamless transition while maintaining best practices to optimize cost efficiency. Drawing on insights from the limitations of existing systems outlined in related papers, this abstract heralds blockchain's prowess in ushering in a new era of reliability, security, and efficiency in university account management.

Acknowledgments

First and foremost, praise and thanks to the Almighty, for His showers of blessings throughout my research work to complete the research successfully. I would like to express deep and sincere gratitude to my thesis supervisor, Associate Prof. Dr Muhammad Hasibur Rashid Chayon for giving me the opportunity to do research and for the continuous support, motivation, enthusiasm, and immense knowledge. His guidance helped me throughout the research and writing of this thesis. I could not have imagined having a better supervisor and mentor for my research study. Besides my advisor, I would like to thank the rest of my thesis committee: Prof Dr. Utpal Kanti Das, Md Shahinur Alam and Md Rashedul Islam for their encouragement, insightful comments, and hard questions. Last but not least, I would like to thank our parents, friends and respondents who have helped us with their valuable suggestions and guidance has been very helpful in various phases of the completion of the research

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

1.1 Research Background

1.1.1 Web2: Also known as Web 2.0, represents the evolution of the World Wide Web from a static, one-way communication model to a dynamic and interactive platform. During the Web2 era, which emerged in the early 2000s, there was a notable shift in internet usage patterns. Users became active contributors and participants rather than passive consumers, engaging in social media, collaborative content creation, and interactive web applications. The rise of platforms like Facebook, YouTube, and Wikipedia exemplifies this shift, highlighting a focus on user-generated content, social networking, and a more interactive and participatory online experience. Web2 has become synonymous with the democratization of content creation and the empowerment of internet users to actively shape and share information in a collaborative digital landscape.

1.1.2 Web3: Web3 represents the next evolution of the internet, emphasizing decentralization, trustlessness, and user empowerment through blockchain technology. Unlike the current web paradigm (Web2), which relies heavily on centralized entities to manage data and transactions, Web3 leverages decentralized networks, smart contracts, and cryptographic principles. In a Web3 environment, users have greater control over their data, identity, and digital assets, thanks to decentralized applications (DApps) and blockchain-based platforms. This decentralized approach not only enhances privacy and security but also aims to create a more transparent and user-centric digital experience. Web3 envisions a shift from traditional, centralized online models to a decentralized, peer-to-peer

internet where users are active participants, fostering a more equitable and inclusive digital ecosystem.

1.1.3 Blockchain: Blockchain is a revolutionary technology that presents a departure from the conventional centralized structures characteristic of Web2-based systems. Unlike traditional databases, blockchain operates as a decentralized, distributed ledger that securely records transactions across a network of computers. Each transaction is bundled into a "block" and linked in chronological order, forming a continuous chain – hence the term "blockchain."

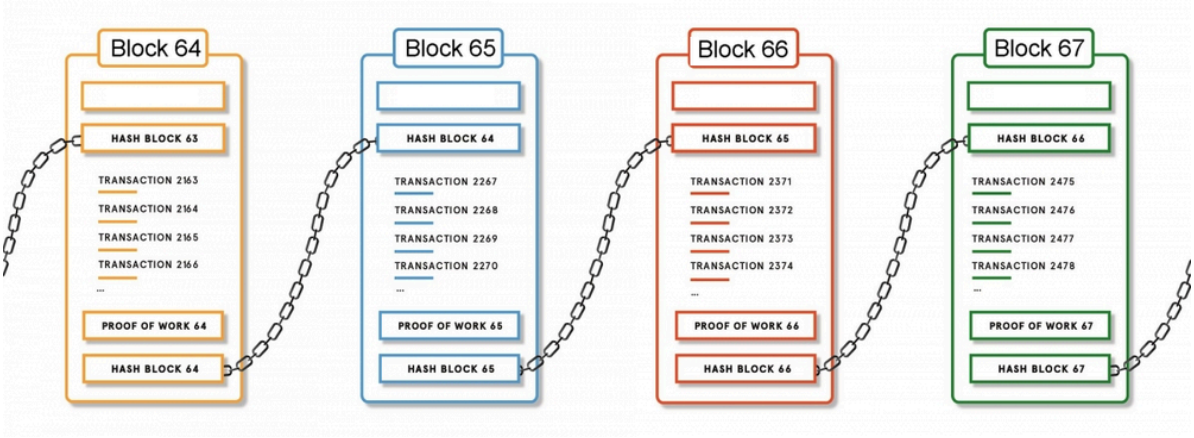

Figure 1.1 - Representation of Connected blocks in Blockchain

This technology offers several transformative features. Firstly, it ensures data security by employing cryptographic techniques, making it extremely difficult for unauthorized parties to alter recorded information. Secondly, blockchain enhances transparency as all transactions are publicly recorded and can be verified by anyone on the network, promoting trust and accountability. Lastly, its decentralized nature removes reliance on a central authority, fostering a more resilient system less susceptible to single points of failure or manipulation.

In essence, blockchain introduces a paradigm shift in data management, providing a decentralized, transparent, and secure framework that significantly contrasts with the limitations of centralized Web2-based systems in university account management. This technology holds the promise of addressing critical issues such as security vulnerabilities, lack of transparency, and adaptability by leveraging its unique architecture and features.

1.1.1 Overview of existing work

The existing landscape of University Accounts Management Systems (UAMS) predominantly operates within the constraints of Web2-based frameworks, characterized by centralized systems that face critical challenges in terms of data security, transparency, and adaptability. These challenges manifest in various forms, including cybersecurity threats, data privacy concerns, and limited accessibility due to centralized control. Traditional UAMS often relies on centralized databases, posing vulnerabilities to single points of failure and potential breaches. Furthermore, the lack of transparency in financial transactions and the susceptibility to unauthorized alterations compromise the integrity of critical records. This current paradigm not only exposes academic institutions to security risks but also hinders their ability to adapt to evolving technological advancements. The limitations of Web2-based UAMS highlight the pressing need for transformative solutions that leverage emerging paradigms such as Web3 and blockchain technology to address the inherent deficiencies and propel these systems into a more secure, transparent, and efficient future.

1.2 Problem Statement

In the rapidly evolving landscape of university accounts management systems, the current reliance on Web2-based architectures poses significant challenges, including vulnerabilities to cyber threats, limited transparency, and inefficiencies in data processing. Despite extensive research exploring the transformative potential of blockchain technology in securing various digital platforms, there is a critical gap in addressing the specific vulnerabilities within university accounting systems. Existing studies highlight the success of blockchain implementations in diverse sectors, such as decentralized marketplaces (Shakila et al., 2021), public service organizations (Shahaab et al., 2021), and messaging applications (Kuchimanchi et al., 2023), underscoring the need for a tailored solution for securing university accounts. The identified platforms, including Ethereum, MongoDB, Node.js, IPFS, and Metamask, showcase remarkable success in different contexts, yet there is a lack of a comprehensive, dedicated framework for fortifying the accounting systems of educational institutions. Therefore, this research aims to bridge this gap by developing a novel Web3-based architecture that integrates the strengths of Ethereum, MongoDB, Node.js, IPFS, and Metamask, ensuring the security, transparency, and scalability required for modern university accounts management systems.

1.3 Importance of the Research

The significance of this research lies at the intersection of pioneering advancements in blockchain technology and the urgent need to fortify university accounts management systems. With the current vulnerabilities inherent in Web2-based architectures, there is a pressing demand for a transformative shift towards Web3 paradigms. This study aims to not only address the critical gap in securing university accounting systems but also to redefine the standards for data integrity, transparency, and efficiency. By leveraging the proven successes of Ethereum, MongoDB, Node.js, IPFS, and Metamask in various domains, this research seeks to tailor their integration into a dedicated Web3 framework specifically designed for the intricacies of university accounts management. The proposed architecture promises to revolutionize the way educational institutions safeguard sensitive financial data, offering a comprehensive solution that aligns with the evolving landscape of digital security. The outcomes of this research have the potential to set a new benchmark for secure and transparent university accounts management systems, ensuring the resilience and adaptability needed to navigate the complexities of the modern academic financial landscape.

1.4 Research Objective

The research objective is nothing short of a transformative reimagining of university accounts management systems, fueled by cutting-edge Web3 technologies and blockchain integration. At its core, this study aspires to fortify the security, transparency, and efficiency of accounting processes within academic institutions, mitigating the vulnerabilities inherent in traditional Web2 architectures. Through a systematic exploration of the strengths offered by Ethereum, MongoDB, Node.js, IPFS, and Metamask, the goal is to craft a Web3-based hybrid model that seamlessly blends the advantages of decentralized, distributed, and secure

systems. The research extends beyond theoretical exploration, aiming to implement a revolutionary university accounts management system that leverages smart contracts, decentralized databases, and cryptographic principles. By pursuing this research objective, the aspiration is not only to pioneer a novel approach to safeguarding financial data but also to inspire a paradigm shift in the realm of educational technology, setting new standards for security, transparency, and operational excellence.

1.5 Research Scope

The research scope encompasses a comprehensive investigation into the integration of Web3 technologies, specifically blockchain, in revolutionizing university accounts management systems. Focusing on Ethereum, MongoDB, Node.js, IPFS, and Metamask, the study delves into the intricate details of their roles in crafting a secure, transparent, and efficient hybrid model. The scope extends to the implementation of this model, transcending theoretical boundaries to create a tangible and innovative university accounts management system. By scrutinizing existing works and identifying gaps and challenges, the research aims to bridge these shortcomings, offering practical solutions that cater to the unique demands of educational institutions. Furthermore, the exploration of blockchain platforms, consensus mechanisms, smart contract functionalities, and security features contributes to a nuanced understanding of how these technologies can be strategically applied to fortify the financial infrastructure of universities. In essence, the research scope spans the theoretical and practical realms, with the overarching goal of elevating the standards of university accounts management through the transformative potential of Web3 technologies.

1.6 Research Hypothesis

The research hypothesis posits that the integration of Web3 technologies, with a specific focus on Ethereum, MongoDB, Node.js, IPFS, and Metamask, into the university accounts management system will lead to a paradigm shift in terms of security, transparency, cost efficient and operational efficiency. It is hypothesized that leveraging the strengths of blockchain, such as decentralized and tamper-proof data storage, smart contract automation, and enhanced user interaction through tools like Metamask, will address the vulnerabilities inherent in traditional Web2 systems. The research further posits that this hybrid model, combining the benefits of both centralized and decentralized approaches, will result in a robust and scalable framework capable of meeting the complex demands of university financial ecosystems. By systematically addressing the identified gaps and challenges in existing works, the research hypothesis anticipates that the proposed model will not only enhance the security of university accounts but also contribute to a broader understanding of the strategic application of Web3 technologies in educational institutions.

Chapter 2. Literature Review

In recent years, many researchers have proposed various architectures and methods to secure different systems using blockchain technology. I have conducted a systematic literature review on securing different digital platforms from various papers, articles, journals, books, conferences and survey papers. In this chapter, I am going to make a discussion on the current state of research in securing accounts and other platforms using blockchain technology and challenges of the other works that I may overcome through my work approaches.

My work is situated at the crossroads of securing vulnerable accounting systems of universities by applying blockchain technology. Blockchain technology has been significantly used in different sectors of software engineering. Securing systems from attackers is one of the most propitious uses of blockchain technology in these recent years of software engineering. Because older architectural systems are vulnerable to different attacks. In order to do so, over the year's research has been looking into blockchain technology and utilizing its core power to assist architecture design and developers at various phases of software development. In my literature review, I've selected papers according to their relevance to securing systems using blockchain technology, the caliber of the research, and the significance of the outcomes..

From the significant research that has been done on blockchain technology to secure different systems, I discovered that there are various methods for securing a system using blockchain platforms including Ethereum, IBM Blockchain, ConsenSys Quorum, Hyperledger Fabric, Corda, Tezos etc. The security of a platform depends on Scalability, Consensus Mechanism, Security Features, Smart Contract Functionality, Interoperability and Standards, Community and Ecosystem, Transaction Costs and Speed, Governance and Upgrades, Use Case Suitability, Regulatory Compliance, Experimental Test Networks of each platform.

(Shakila, et al., 2021) developed A Decentralized Marketplace Application based on Ethereum Smart Contract. Implemented using Truffle and Solidity, the system leverages Ethereum smart contracts and web3.js for client-side interaction. Analyzing its performance on the Kovan test network, the application demonstrates minimal transaction fees (0.1524472 eth) and efficient processing (3.5 seconds average runtime, 4.6 gwei gas consumption). Comparative analysis with major centralized platforms like eBay and Amazon reveals the system's cost-effectiveness, offering higher profit margins for sellers and reduced costs for buyers. The study emphasizes the system's security, user-friendliness, and potential for broader deployment beyond testnets, suggesting future evaluations focusing on various business metrics and user satisfaction in live environments.

(A.Shahaab, et al., 2021) The paper addresses the challenges faced by Public Service Organizations (PSOs) due to disparate legacy systems, proposing a Proof of Concept (POC)

for a blockchain-based interoperability and data sharing system. Focused on Registration of Overseas Entities and Beneficial Owners (ROEBO) legislation in the UK, the POC demonstrates real-time collaboration between Companies House UK and other PSOs using a hybrid blockchain setup. The POC aims to synchronize data across PSOs, reduce redundant citizen interactions, and enhance the integrity of companies' registers. The implementation involved stakeholder engagement, understanding business processes, identifying suitable DLTs, prototype development, and continuous refinement based on user feedback. The POC showcases the potential for DLTs to streamline PSOs' operations, improve data synchronization, and mitigate fraud, though challenges remain in stakeholder engagement, skill gaps, regulatory uncertainty, and international expansion.

(W. Zhou, et., al 2022) The paper examines the integration of blockchain into accounting cyber security, highlighting its potential advantages in enhancing reliability and transparency while addressing rising cyber threats. It underscores blockchain's role in eliminating intermediaries, emphasizing strategies to secure nodes, ensure information integrity, and strengthen regulatory frameworks. However, it also emphasizes challenges, including cyber risks, regulatory gaps, and the scarcity of skilled professionals. Overall, it underscores blockchain's transformative potential in accounting but emphasizes the need for comprehensive measures to address challenges for successful implementation.

(A. Kuchimanchi et. al, 2023) They developed a decentralized chatting app exploring how blockchain technology could revolutionize messaging and data security. By harnessing

blockchain's strengths—privacy, decentralization, and immutability—they proposed a decentralized chat program. This innovative approach utilized a distributed hash table (DHT) and blockchain to secure communication, highlighting the power of decentralization in bolstering security and removing middlemen. The paper also delved into the advantages and complexities of decentralized, centralized, and distributed systems within blockchain, shedding light on their unique strengths. Their methodology focused on implementing Ethereum, smart contracts, encryption methods, and deployment strategies to construct this groundbreaking chat application. Finally, the results showcased its operation on a local server, marking a significant step toward secure and anonymous communication methods.

(N. A Thabet et. al, 2021) This paper introduces a Query Engine tailored for blockchains, aiming to streamline data access and analysis across various blockchain platforms like Ethereum and Hyperledger. By leveraging Smart Contracts and Solidity, it provides a standardized method for developers and analysts to retrieve and process blockchain-stored information. However, while it significantly enhances data accessibility, querying large datasets might demand substantial computational resources. This engine marks a significant advancement in blockchain data utilization, though further optimization is needed to handle extensive data queries more efficiently.

(R. Gupta et al, 2020) The paper explores the vast potential of blockchain technology, especially its impact on the financial sector and accounting practices. It highlights the transformative power of blockchain, particularly in areas like smart contracts, auditing, and

fair access using dynamic control. The document delves into the benefits of blockchain, such as enhanced security, audit trails, and decentralized control. It outlines how blockchain can revolutionize banking, finance, and trade through features like smart assets, smart contracts, and improved transaction tracking. However, it also discusses challenges like performance issues, privacy concerns, and the need for regulatory frameworks. Ultimately, the paper emphasizes blockchain's role in reducing fraud, improving transparency, and reshaping various industries.

(D. Čeke et al, 2022) The paper delves into optimizing smart contracts on the Ethereum network to reduce execution costs, measured in gas. It outlines a methodology encompassing several optimization steps, focusing on variables, memory usage, loops, functions, and more. The study emphasizes efficient data types, variable packing, memory vs. storage usage, constants, loop optimizations, function visibility, short-circuiting, and removing useless code. Each step provides specific guidelines and examples for gas-efficient coding practices. The conclusion highlights the importance of developer choices in creating gas-optimized smart contracts and the need for in-depth analysis and application of optimization techniques.

(Karim, et al, 2022). This study explores the acceptance of blockchain technology among Indonesian bankers from the top ten banks, focusing on factors influencing their intentions. Using the UTAUT model, eight factors were assessed, revealing that performance expectancy, social influence, habit, and personal innovativeness significantly impact bankers' intentions to adopt blockchain. However, effort expectancy, facilitating conditions, hedonic motivation, and price value did not show significant effects. The research emphasizes the need to enhance bankers' knowledge and habits regarding blockchain to showcase its

efficiency, speed, and transparency benefits. Recommendations include investing in training, understanding technology-associated risks, and considering this study as a foundation for future research in Indonesian banking's blockchain adoption.

Based on the literature review I did, I can identify some major gaps, limitations, and challenges. Considering this wealth of research, my choice of Ethereum, MongoDB, Node.js, IPFS, Metamask, and a hybrid architecture of blockchain is strategically grounded. Ethereum stands out for its robust smart contract functionality, enabling secure and transparent transactions, as exemplified by Shakila et al.'s (2021) decentralized marketplace application. Leveraging MongoDB ensures efficient data management and scalability, crucial in handling extensive transactional data, as seen in the studies by Shahaab et al. (2021) and Thabet et al. (2021). Node.js, being an efficient runtime environment, complements the architecture, facilitating rapid development and deployment of blockchain-based systems, as highlighted in Kuchimanchi et al.'s (2023) work on decentralized chat apps. IPFS (InterPlanetary File System) further bolsters security by decentralizing file storage and retrieval, a feature vital in ensuring data integrity and immutability, as discussed in A. Kuchimanchi et al.'s (2023) research. Incorporating Metamask enhances user interaction and security, providing a seamless interface for users to interact with Ethereum-based applications. Finally, a hybrid architecture approach, as explored by Shahaab et al. (2021), offers the potential to combine the strengths of multiple blockchain platforms, ensuring interoperability, scalability, and improved security features. This amalgamation aligns with the findings in the literature, addressing various aspects such as scalability, security features, interoperability, and user

experience, creating a robust and comprehensive framework for securing vulnerable accounting systems in universities.

(Liu, et al, 2023) The paper explores the integration of blockchain technology into IoT finance, particularly focusing on enhancing the efficiency and security of supply chain finance. Recognizing the challenges in traditional supply chain finance, the study designs and implements a financial management platform that combines blockchain with supply chain mechanisms. Leveraging decentralized features and smart contracts, this platform enables synchronization of bank account systems, automates fund flows, supervises processes, and facilitates automatic settlements. The system's architecture, designed using unified modeling language (UML) and the model view controller (MVC) structure, demonstrates improved security and efficient transaction processing. For core enterprises within the supply chain, this platform offers rapid funding for multiple suppliers, particularly benefiting smaller entities by resolving their financing challenges. Moreover, it highlights the potential for subsequent financial services, including data analysis-driven risk assessment, decision support, and establishing effective credit rating models and risk management frameworks based on stored supply chain data. Ultimately, the proposed financial platform stands to significantly enhance financing efficiency and capital flow within the supply chain ecosystem.

(P. D. Dozier et al, 2023)The article delves into the evaluation process of blockchain technology within the financial services industry, examining how organizations assess its potential value and innovation. Through a grounded theory approach involving 12 financial service organizations, the study uncovers a three-step process—understand, organize, and

test—that contributes to the creation of a Proof-of-Value (POV) model. Interestingly, despite recognizing blockchain's transformative potential, organizations often perceive it as a lower priority due to unclear paths to value. They engage in side investigations and utilize consortiums to link to external knowledge, attempting to reduce uncertainty and match the technology to existing organizational problems. Large organizations formalize their investigations, while smaller ones lean on limited internal resources and consortiums. The study reveals that the evaluation process primarily starts informally, using side investigations, and emphasizes the importance of industry collaboration and use case identification. The findings provide a model for organizations to evaluate blockchain and offer insights for both practitioners and researchers in understanding innovation decision-making processes within technological disruptions.

(Guo et al, 2016) The article explores the potential of blockchain technology in transforming the banking industry, particularly in payment clearing systems, credit information, and financial transactions. It highlights how blockchain could enhance efficiency, reduce costs, and improve security in various banking processes. The benefits include faster cross-border transactions, improved credit data sharing, and streamlined supply-chain finance. However, challenges like regulation, efficiency concerns, and security issues need addressing. The article suggests solutions such as regulatory sandboxes, industry standards, and more robust information access mechanisms. Despite these challenges, the article remains optimistic about blockchain's potential to revolutionize banking in the near future.

(Abad-Segura et al, 2021) The article delves into the realm of blockchain technology's impact on secure accounting management, exploring its evolution and current research trends

between 2016 and 2020. It identifies key areas of investigation, highlighting the rise in publications and emerging research directions globally. By analyzing 1130 articles from the Scopus database, the study pinpoints seven primary lines of work and ten significant emerging research areas. This comprehensive review sheds light on the technology's potential applications across various sectors, emphasizing its role in reducing risks, eliminating errors, and enhancing transparency in accounting. The findings serve as a valuable guide for academia, researchers, and investment programs, offering insights into past and future trends in this evolving field.

In essence, the research will not only formulate these objectives but will also implement them practically to bring about substantial improvements in the university accounts management system. By deploying the proposed hybrid UAMS model and addressing these key areas, the system will be fortified against security threats and data breaches, guaranteeing data privacy, immutability, and data accuracy.

Chapter 3. Research Methodology

3.1 Scenario

Currently, university accounts management systems primarily operate on traditional Web2 structures, relying on centralized servers for data storage, processing, and management. In this centralized system, decision-making authority is concentrated within a single entity, and users interact with the system through web interfaces connected to a backend server. While this model has proven effective in handling routine tasks, it is susceptible to security vulnerabilities and single points of failure. The shift towards a hybrid Web2-Web3 model in university accounts management represents a transformative leap. With the integration of blockchain technology, the decentralized and secure nature of Web3 is introduced. In the updated scenario, critical functionalities such as transaction validation, data storage, and access control are executed through smart contracts on a public blockchain like Ethereum. This decentralized approach ensures transparency, immutability, and resistance against unauthorized alterations. The introduction of IPFS enhances data storage by utilizing a peer-to-peer method, and the overall architecture fosters collaborative decision-making among nodes. This transition brings forth a more resilient, transparent, and secure university accounts management system, addressing critical issues faced by conventional Web2 structures.

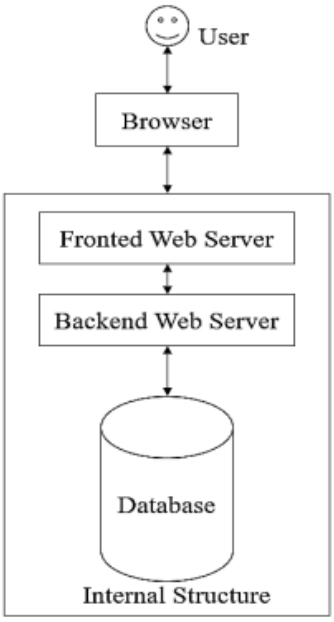

Figure 3.1 - Traditional Centralized Architecture of University Accounts Management System

3.2 Proposed Architecture

The proposed architecture for the University Accounts Management System (UAMS) represents a groundbreaking shift from conventional Web2 structures to a hybrid Web2-Web3 model, leveraging the transformative capabilities of blockchain technology. In the initial Web2 component, users interact with a traditional web-based structure, engaging with a frontend that communicates with a backend server responsible for data processing and business logic. The innovation occurs during the integration of blockchain/Web3 functionalities into this existing architecture. Here, smart contracts on a public blockchain, such as Ethereum, take center stage, handling crucial tasks like transaction validation, data storage, and access control. The data storage architecture adopts a decentralized approach,

utilizing the blockchain's distributed ledger, while IPFS (InterPlanetary File System) further contributes to decentralized and secure file storage. Users experience a seamless interface that combines traditional web interactions with blockchain-related functionalities. This hybrid architecture ensures enhanced data integrity, transparency, and resistance against unauthorized alterations or security breaches, addressing longstanding challenges in traditional university accounts management systems.

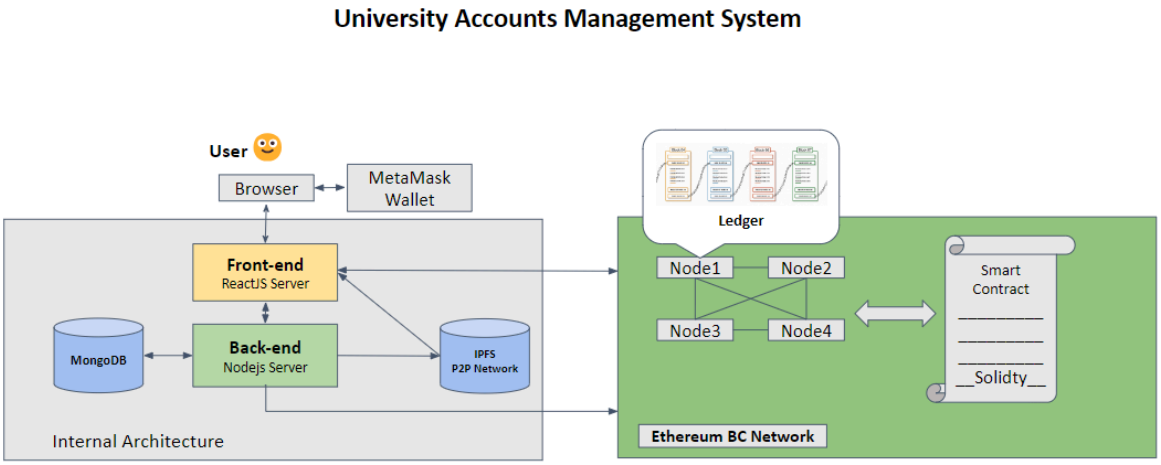

Figure 3.2 - Proposed Hybrid Architecture of university accounts management system

3.3 Components of the Architecture

3.3.1 Centralized Systems[internal architecture]

In a centralized system, control and decision-making authority are concentrated within a single entity or location. All data, resources, and functionalities are managed and controlled by this central authority. Examples include traditional organizational structures where decisions flow from a hierarchical top-down approach. In technology, a centralized system might involve a single server or data center managing all processes and information. While they may be efficient, centralized systems are prone to single points of failure and can be vulnerable to security breaches.

3.3.2 Decentralized Systems

Decentralization disperses control across multiple entities or nodes, allowing them to operate independently while still working towards common goals. Decentralized systems distribute data, authority, and processing across various nodes or servers, often in a peer-to-peer network. In technology, blockchain is an example of a decentralized system where information is stored across multiple nodes, ensuring transparency and reducing the risk of a single point of failure. Decentralization often leads to increased resilience and can enhance security by eliminating central vulnerabilities.

3.3.3 Distributed Systems

Distributed systems are a broader concept where components or nodes collaborate to achieve a common objective. Unlike decentralization, distribution may not imply autonomy. These systems can have various degrees of centralization or decentralization within the distributed

network. Distributed systems often involve multiple interconnected nodes that communicate and share resources or tasks. For instance, cloud computing employs a distributed model where resources are spread across various servers or data centers, allowing for scalability, redundancy, and better performance.

My proposed architecture for the University Accounts Management System involves a shift from a conventional Web2 structure towards a hybrid Web2-Web3 model, leveraging blockchain technology for enhanced security and functionality.

Table 3.1: Comparison among centralized, decentralized and distributed systems

Feature	Centralized	Decentralized	Distributed
Decision Making	Central entity makes all decisions	Individual nodes make decisions	Collaborative decision making among nodes
Data Storage	Data stored in a central location	Data stored on individual nodes	Data replicated across multiple nodes
Processing	Processing done by central entity	Processing done by individual nodes	Processing shared among nodes
Scalability	Limited scalability	Highly scalable	Highly scalable
Fault Tolerance	Single point of failure	Fault tolerant	Fault tolerant
Security	Vulnerable to attacks on central entity	More secure	More secure

In the Web2-Web3 hybrid architecture, the system transitions from a traditional centralized server-based approach to a more decentralized and secure framework. Here’s an overview:

3.3.4 Web2 Component

Initially, the architecture consists of a traditional web-based structure. A user interacts with a browser that connects to the system's frontend. This frontend, as in conventional systems, communicates with a backend server that manages data processing and business logic.

3.3.4 Integration of Blockchain/Web3

The transition occurs when integrating blockchain/Web3 functionalities into the existing Web2 structure. The backend architecture incorporates modules or smart contracts on a public blockchain (such as Ethereum). These smart contracts handle critical functionalities like transaction validation, data storage, and access control, ensuring data immutability and transparency.

3.5.4 Decentralized Database

Instead of relying solely on a centralized database, the system decentralizes data storage by utilizing the blockchain's distributed ledger. This ledger securely records transactional data across multiple nodes, ensuring transparency and tamper-proof records.

3.5.5 User Interaction

Users interact with the system through an interface that integrates both traditional web-based interactions and blockchain-related functionalities. For instance, a user may perform basic tasks via the frontend, while specific actions involving financial transactions or sensitive data are securely managed through blockchain-powered processes.

3.3.5 Storage Technologies

There are 3 data storages in my system. They are -

3.3.5.1 Blockchain Storage

Blockchain serves as the backbone of our University Accounts Management System (UAMS), providing a secure and transparent ledger for transactional records. In this decentralized and distributed ledger technology, each transactional record is encapsulated within a block. These blocks are cryptographically linked, creating an immutable chain. The inclusion of a cryptographic hash of the previous block, a timestamp, and transaction data in each block ensures the integrity and security of the recorded information. Once data is added to the blockchain, it becomes virtually tamper-proof, offering a robust foundation for recording and verifying transactions across a network of computers. The decentralized nature of the blockchain ensures that there is no central point of failure, and the distributed consensus mechanism enhances the overall reliability and security of the system.

3.3.5.2 IPFS (InterPlanetary File System)

In addition to blockchain, our UAMS incorporates the InterPlanetary File System (IPFS) for efficient and decentralized file storage. IPFS is a peer-to-peer protocol that transforms the traditional approach to content storage and sharing. Unlike centralized web servers, IPFS utilizes a distributed network where files are stored across multiple nodes. Each file is referenced by a unique hash instead of a traditional URL, making content retrieval more resilient and efficient. This decentralized approach aligns with our goal of reducing reliance on centralized storage systems, enhancing data accessibility, and ensuring the integrity of essential documents.

3.3.5.3 Database Management (MongoDB)

To efficiently manage the diverse and dynamic data associated with university accounts, we have chosen MongoDB as our database solution. MongoDB, a NoSQL database, provides a flexible and scalable storage option, accommodating various types of information. In our UAMS, MongoDB is utilized to store temporary data that may need frequent updates, such as user profile information, including contact details, addresses, and personal preferences. This choice offers a responsive and adaptable solution for managing user-specific information within the system. Additionally, MongoDB's document-based structure aligns with the requirements of our dynamic data models, making it an ideal choice for handling diverse student and administrative account details.

In Ethereum Blockchain and IPFS my architecture involves a strategic distribution of data among different storage solutions. In the Ethereum blockchain, I store final records that do not require frequent updates, such as hashed student IDs, account IDs, transaction details, and various financial parameters. This ensures data immutability and transparency on the blockchain. In contrast, IPFS is employed for storing large and important files, such as invoices and certificates, where the cost-effectiveness of storage is a priority. By utilizing IPFS for large file storage, we mitigate the cost implications associated with storing voluminous data on the Ethereum blockchain, where gas fees are directly influenced by the amount of data being stored. This three-tiered approach to data storage and management enhances efficiency, security, and cost-effectiveness in our UAMS.

Let's have a look at the data storing architecture -

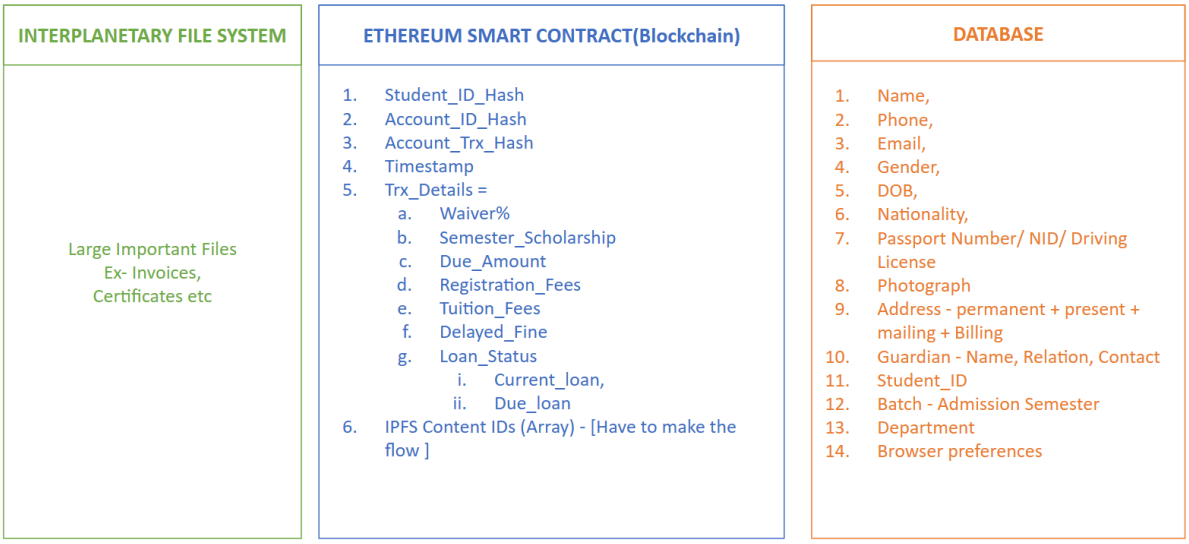

Figure 5.3 - Data Storing Plans

3.4. Features

I've tried to make the system as user friendly as possible. Here are several user-friendly features that I have implemented in my system.

3.4.1 Student/Accountant Authentication (Signup/Login)

The University Accounts Management System (UAMS) ensures secure access through a robust authentication process. Students and accountants go through a signup/login mechanism to access the system. This step ensures that only authorized individuals can interact with the UAMS, enhancing overall security.

3.4.2 Admin Panel Controls for Accountants

The admin panel plays a crucial role in managing the system. During the smart contract deployment, the admin is granted access to control and assign roles to accountants. Admins have the authority to add or remove accountant access, providing flexibility in managing the workforce responsible for handling financial transactions.

3.4.3 Student-Friendly UI (React Framework)

The user interface of UAMS is designed with students in mind, leveraging the React framework. This ensures a user-friendly and intuitive experience for students interacting with the system. The use of React allows for dynamic and responsive interfaces, enhancing overall usability.

3.4.4 Pre Checking and Transaction Verification

UAMS incorporates a pre-checking mechanism to validate transactions. When students pay their dues, a copy of the invoice is sent to their pending list for verification. Users can review transactions and report any discrepancies. If an issue is reported, the transaction does not proceed to the blockchain. Accountants address reported problems, ensuring accurate and secure data entry into the blockchain.

3.4.5 Improved Security through Blockchain Integration

Security is a top priority in UAMS, and the integration with blockchain significantly enhances it. Blockchain's tamper-proof nature ensures the integrity and security of transactional data. This feature minimizes the risk of unauthorized access or data manipulation, providing a robust security layer to the entire system.

Chapter 4. Implementation Result and Discussion

4.1 Tools and Techs

The choice of tools and technologies in developing our University Accounts Management System (UAMS) is strategic, aiming to create a robust, scalable, and secure platform.

4.1.1 ReactJS

ReactJS is employed for building the user interface of UAMS. Its component-based architecture enables the creation of modular and reusable UI elements, facilitating a responsive and dynamic user experience. The virtual DOM in React enhances performance by efficiently updating and rendering UI components.

4.1.2 NodeJS and ExpressJS

NodeJS, paired with ExpressJS, serves as the backend framework. NodeJS provides a non-blocking, event-driven architecture, making it well-suited for handling concurrent requests. ExpressJS, being a minimal and flexible Node.js web application framework, streamlines the development of the server-side of UAMS, ensuring efficient and speedy operations.

4.1.3 MongoDB

MongoDB, a NoSQL database, is chosen for its scalability and flexibility. It allows seamless handling of diverse data types within the university accounts management system, ensuring efficient storage and retrieval of information. The document-oriented nature of MongoDB aligns well with the dynamic and evolving data requirements of UAMS.

4.1.4 IPFS Pinata

IPFS Pinata is integrated into the system to address the storage needs for large data in a decentralized network. Pinning data on IPFS ensures its availability and resilience, providing a distributed solution for storing essential files such as invoices and certificates securely. Using their api its easier for users to integrate this network with the backend.

4.1.5 Ethereum Blockchain

Ethereum is selected as the underlying blockchain infrastructure for UAMS due to its global acceptance, user-friendly interface, and cost efficiency. The smart contract functionality of Ethereum enables the implementation of secure and transparent transactions, crucial for managing accounts within the university.

4.1.6 Smart Contract

The Smart Contract is the core component of the blockchain integration, written in Solidity. It functions as a self-executing contract with the terms of the agreement directly written into code. In the context of the University Accounts Management System (UAMS), these smart contracts encode the business logic governing transactions and interactions within the blockchain, ensuring a secure, transparent, and automated execution of predefined rules.

4.1.7 Metamask

Metamask serves as the digital wallet within the UAMS ecosystem, enabling users to interact seamlessly with the Ethereum blockchain. It acts as a bridge between the traditional web and the decentralized world of blockchain, allowing users to securely manage their accounts, sign transactions, and authenticate their identity. Metamask plays a pivotal role in enhancing user experience and accessibility within the blockchain environment.

4.1.8 Ether JS

Ether JS is an essential npm framework utilized to streamline interactions between the UAMS and the Ethereum network. It provides a set of JavaScript libraries and utilities that facilitate communication with the Ethereum blockchain and Metamask. By integrating Ether JS into the development stack, the UAMS ensures a smooth and efficient flow of data and transactions, enhancing the overall functionality of the system.

4.1.9 HardHat

HardHat serves as the testing framework for the smart contracts developed within the UAMS. Before deploying smart contracts to the live Ethereum network, rigorous testing is imperative to identify and rectify potential issues. HardHat allows developers to conduct comprehensive testing, including unit tests and scenario simulations, ensuring the reliability, security, and functionality of the smart contracts in diverse situations. This testing framework plays a crucial role in minimizing risks and enhancing the overall stability of the UAMS in a live environment.

4.1.10 Alchemy

Alchemy offers a simplified Ethereum node cluster for universities, enabling easy integration of blockchain technology into account management systems. By providing hosted Ethereum nodes, Alchemy streamlines the process, allowing universities to develop and deploy decentralized applications without managing their own nodes or wallets. This service simplifies the implementation of blockchain solutions for university account management, enhancing accessibility and ease of use.

4.1.11 Etherscan

Etherscan provides invaluable tools and insights for university account management on the Ethereum blockchain. This platform enables universities to explore and analyze transactions, addresses, tokens, and other crucial data within their blockchain-based accounts. It offers transparency and visibility into account activities, facilitating efficient monitoring and auditing of university-related transactions and records.

The University Accounts Management System (UAMS) is a robust and scalable platform strategically developed using cutting-edge tools and technologies. Employing ReactJS for a dynamic user interface and NodeJS with ExpressJS for efficient backend operations, UAMS ensures a responsive and streamlined experience. MongoDB, a NoSQL database, handles diverse data types, aligning with the system's dynamic requirements. Integration of IPFS Pinata addresses large data storage needs in a decentralized network, while Ethereum blockchain, along with Smart Contracts and tools like Metamask and Ether JS, ensures secure, transparent transactions. Alchemy and Etherscan enhance accessibility and monitoring, offering simplified integration and insights into blockchain-based university account management.

4.2 Results

4.2.1 Implementation of Ethereum Blockchain

- Successful integration of Ethereum blockchain technology to enhance data security and transparency within the university accounts management system.
- Utilization of smart contracts facilitated smoother, automated transactions, reducing manual errors and enhancing efficiency.
- Implementation of EtherJS and MetaMask ensured seamless interaction with the Ethereum network, providing a user-friendly experience.

4.2.2 MERN Stack Development

- Effective utilization of MongoDB, Express.js, React.js, and Node.js components for developing a robust, scalable, and responsive system.
- MongoDB ensured flexible data storage and retrieval, contributing to the system's adaptability and scalability.
- React.js and Node.js facilitated a dynamic and interactive user interface, improving user experience and system responsiveness.

4.2.3 System Performance

- Enhanced data security through cryptographic hashing and encryption methodologies inherent to the blockchain.
- Improved transactional transparency and traceability due to blockchain's immutable nature, enabling better audit trails and accountability.
- Increased system reliability and fault tolerance through decentralized data storage and processing.

4.2.4 System Efficiency

- Optimized gas fee for cost efficiency
- Less data error due to pre filtering of data before inserting it into blockchain
- Gas fee reduced due to using IPFS Pinnata.
- Store the important data as a PDF to improve security
- Adaptable system architecture for most of the existing university accounts systems

Snapshots of the app -

Figure 4.1 - Confirmed Transaction History List fetched from Blockchain

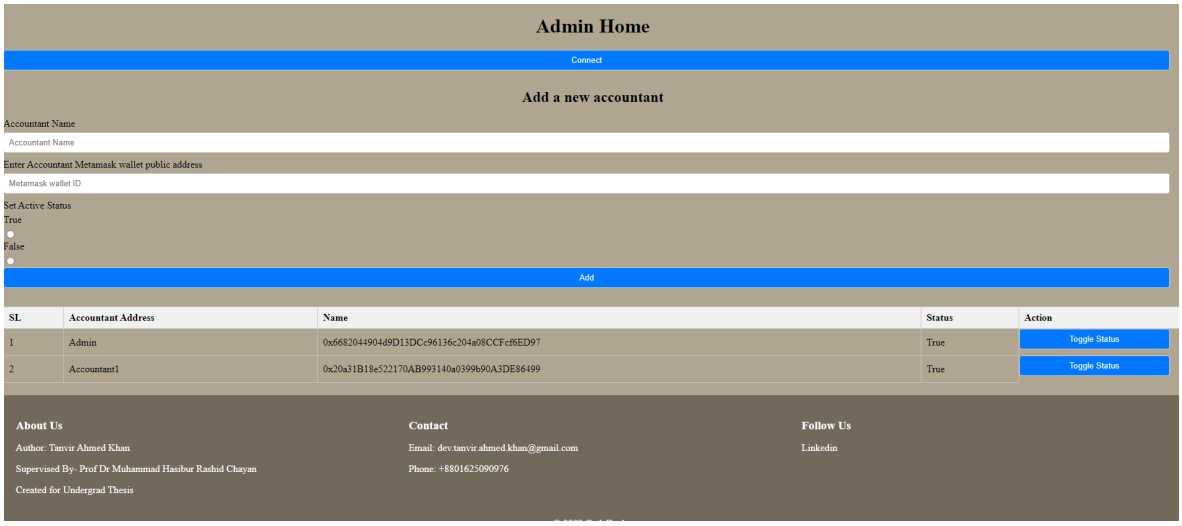

Figure 4.2 - Admin Panel for controlling access of accountants

IUBAT Payment Invoice Report

Invoices ID: 656d9bd218ebcf6bc5bf9834
Student ID: 20203036
Status: uploaded
Last Date: Thu Dec 07 2023 06:00:00 GMT+0600 (Bangladesh Standard Time)
Paid Amount: 77860
Payment Date: Mon Dec 04 2023 15:31:19 GMT+0600 (Bangladesh Standard Time)
Due Amount: 77860

Payment Details:

SL. Cause ---------- Amount
1. Reg Fee ---------- 12860
2. Tutuin Fee ---------- 65000

Figure 4.3 - Payment Invoice Report

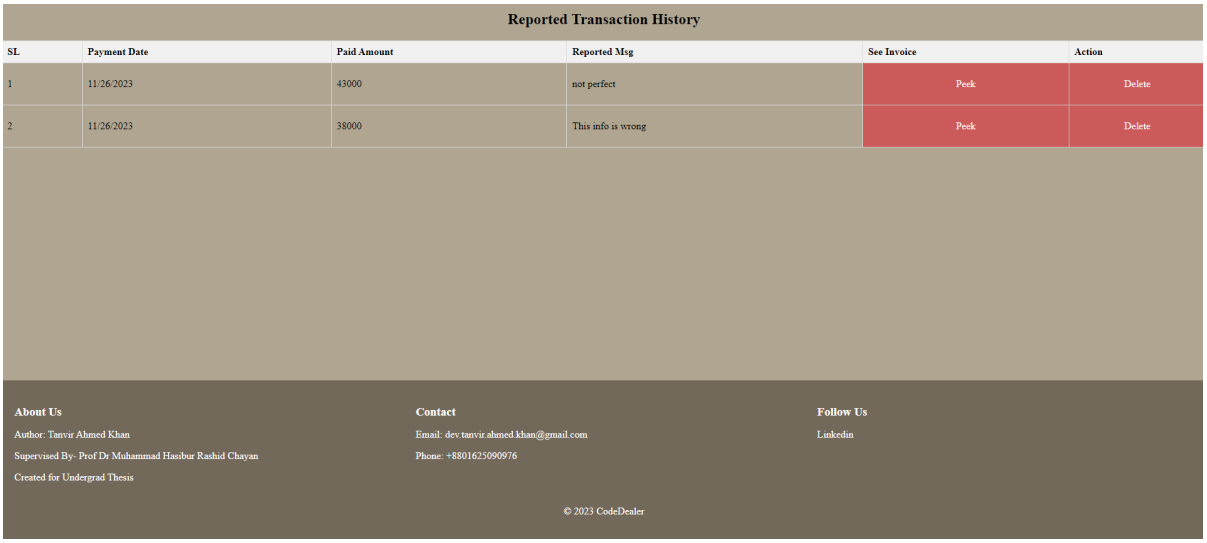

Figure 4.4 - List of Reported Transactions from Database

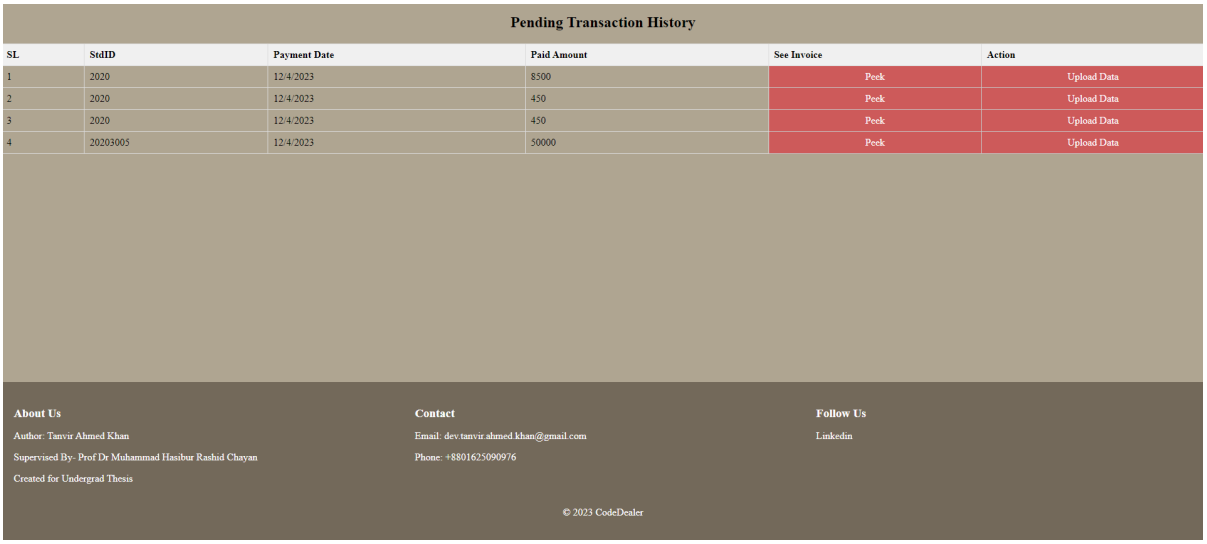

Figure 4.5 - Pending Confirmed Transaction List waiting for upload into blockchain

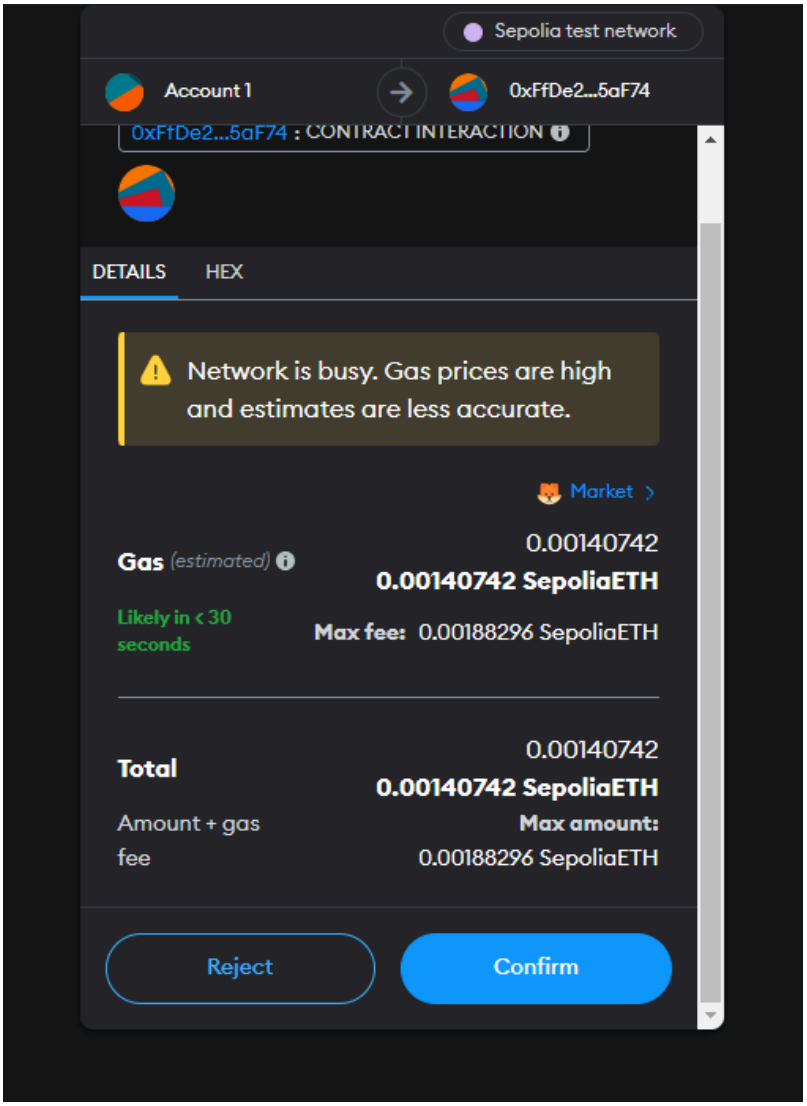

Figure 4.6 - Metamask Transaction report for a particular transaction

4.3 Discussion

The University Accounts Management System (UAMS) is meticulously designed, leveraging advanced technologies to ensure a secure, scalable, and user-friendly platform. The utilization of ReactJS facilitates the creation of a modular and responsive user interface, enhancing the overall user experience. With MongoDB serving as the backend database, the system accommodates diverse data types efficiently. Integration of IPFS Pinata addresses the

challenge of storing large data in a decentralized network, ensuring resilience and security for essential files. Ethereum blockchain, coupled with Smart Contracts, Metamask, and Ether JS, guarantees secure and transparent transactions, positioning UAMS at the forefront of innovative and reliable university account management solutions.

4.3.1 Benefits of Blockchain Integration

- The utilization of Ethereum blockchain provided unparalleled data security and transparency, critical in university financial systems.
- Smart contracts streamlined processes, automating transactions, reducing human error, and enhancing operational efficiency.
- The decentralized nature of blockchain minimized the risk of single points of failure, ensuring system reliability.

4.3.2 MERN Stack Advantages

- The MERN stack allowed for seamless development, offering flexibility, responsiveness, and scalability to the system.
- MongoDB's NoSQL database provided the necessary adaptability for handling diverse data structures.
- React.js and Node.js contributed to creating a user-friendly interface and ensuring efficient backend operations.

4.3.3 Future Considerations

- Further scalability measures to accommodate the system's growth and evolving user requirements.
- Continuous optimization of smart contracts and blockchain functionalities for improved performance.
- Potential enhancements in UI/UX and system accessibility to cater to a broader user base.

Chapter 5. Conclusion

5.1. Conclusion:

The transformation from traditional Web2-based University Accounts Management Systems to a hybrid Web2-Web3 blockchain-integrated architecture marks a significant step toward addressing critical challenges in data security, transparency, and efficiency. By leveraging the immutability and decentralization offered by blockchain technology, along with the distributed nature of IPFS and the structured data management of databases, this system presents a novel approach to handling financial records securely and transparently.

Through the implementation of Ethereum blockchain and the MERN stack, my system ensures heightened security, scalability, and fault tolerance while offering a user-friendly interface. The utilization of smart contracts automates transactional processes, providing a robust framework for secure interactions and enhancing overall trust among stakeholders. Moreover, the hybrid architecture strategically combines the strengths of both Web2 and Web3 paradigms, enabling a seamless transition from legacy systems to a more advanced, secure, and efficient infrastructure.

This research lays the groundwork for future advancements in university financial management systems, not only ensuring the integrity and security of transactional data but also pioneering a new era of decentralized and transparent financial operations. As the digital landscape continues to evolve, the integration of blockchain-based solutions in academia

promises to revolutionize traditional methods, offering enhanced security, transparency, and efficiency for managing university accounts.

5.2. Limitations

Despite the successful testing on the Sepolia testnet, the inability to conduct experiments on the Ethereum Mainnet poses a significant technical limitation in fully understanding how the proposed architecture behaves in a real-world, production environment. This limitation stems from the high costs associated with transactions and deployment on the Ethereum Mainnet. The architecture relies on users accessing the Ethereum blockchain through MetaMask, which introduces another constraint as it mandates user adoption of this specific wallet for interaction. Additionally, the cost of real ethers poses a financial challenge, making it impractical for widespread adoption, especially in resource-constrained environments. The dependence on expensive ethers may hinder the scalability and accessibility of the University Accounts Management System (UAMS), limiting its potential impact. Furthermore, the research acknowledges that the proposed hybrid architecture might face challenges related to the dynamic and evolving nature of blockchain technologies, requiring continuous optimization and adaptation to keep pace with industry developments. These limitations emphasize the need for further research and adjustments to enhance the feasibility and effectiveness of the proposed system in diverse real-world scenarios.

5.3. Future work

In the future, we can improve the University Accounts Management System by making our own special blockchain network. This network would be designed to be both inexpensive and secure, and it would operate as a private network, specifically customized for the needs of our University Accounts Management System (UAMS). Right now, our research is based on existing blockchain platforms like Ethereum. However, there's room for us to create our own network that suits the unique requirements we've identified. By doing this, we can overcome the challenges related to high transaction costs and the reliance on external platforms. Having our private network gives us more control and flexibility for UAMS. Additionally, we can design a special agreement method that fits the way our university works, making things more scalable and less dependent on costly resources. This future direction in our research aims to make the system better, more affordable, and more efficient, contributing to the ongoing development of decentralized technologies for university account management.

References

U. K. Shakila and S. Sultana, "A Decentralized Marketplace Application based on Ethereum Smart Contract," 2021 pp. 1-5, doi: 10.1109/ICCIT54785.2021.9689879.

A. Shahaab, I. Khan, R. Maude and C. Hewage, "A Hybrid Blockchain Implementation to Ensure Data Integrity and Interoperability for Public Service Organisations," 2021, pp. 295-305, doi: 10.1109/Blockchain53845.2021.00047.

W. Zhou and M. Sun, "Accounting Cyber Security Based on Blockchain," 2022 IEEE Asia-Pacific Conference on Image Processing, Electronics and Computers (IPEC), Dalian, China, 2022, pp. 1254-1257, doi: 10.1109/IPEC54454.2022.9777549.

A. Kuchimanchi, M. Vagdevi, M. Reddy, G. Avugaddi and S. S. Kumar, "Chatease: A Blockchain based Chat Application," 2023 2nd International Conference on Applied Artificial Intelligence and Computing (ICAAIC), Salem, India, 2023, pp. 1171-1176, doi: 10.1109/ICAAIC56838.2023.10140347.

N. A. Thabet and N. Abdelbaki, "Efficient Quering Blockchain Applications," 2021 3rd Novel Intelligent and Leading Emerging Sciences Conference (NILES), Giza, Egypt, 2021, pp. 365-369, doi: 10.1109/NILES53778.2021.9600533.

R. Gupta, V. K. Shukla, S. S. Rao, S. Anwar, P. Sharma and R. Bathla, "Enhancing Privacy through “Smart Contract” using Blockchain-based Dynamic Access Control," 2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM), Dubai, United Arab Emirates, 2020, pp. 338-343, doi: 10.1109/ICCAKM46823.2020.9051521.

D. Čeke, S. Kunosić and N. Buzađija, "Smart Contract execution costs optimisation on blockchain network," 2022 45th Jubilee International Convention on Information,

Communication and Electronic Technology (MIPRO), Opatija, Croatia, 2022, pp. 1442-1447, doi: 10.23919/MIPRO55190.2022.9803805.

Karim, S., Rabbani, M.R., & Bawazir, H.S. (2022). Applications of Blockchain Technology in the Finance and Banking Industry Beyond Digital Currencies. Blockchain Technology and Computational Excellence for Society 5.0.

Liu, H.; Yang, B.; Xiong, X.; Zhu, S.; Chen, B.; Tolba, A.; Zhang, X. A Financial Management Platform Based on the Integration of Blockchain and Supply Chain. Sensors 2023, 23, 1497. https://doi.org/10.3390/s23031497

P. D. Dozier and T. A. Montgomery, "Banking on Blockchain: An Evaluation of Innovation Decision Making," in IEEE Transactions on Engineering Management, vol. 67, no. 4, pp. 1129-1141, Nov. 2020, doi: 10.1109/TEM.2019.2948142.

Guo, Y., Liang, C. Blockchain application and outlook in the banking industry. Finance Innov 2, 24 (2016). https://doi.org/10.1186/s40854-016-0034-9

Abad-Segura, E.; Infante-Moro, A.; González-Zamar, M.-D.; López-Meneses, E. Blockchain Technology for Secure Accounting Management: Research Trends Analysis. Mathematics 2021, 9, 1631. https://doi.org/10.3390/math9141631

D. Li, "Study on the Web 2.0-based Internet applications in the university libraries," 2013 2nd International Symposium on Instrumentation and Measurement, Sensor Network and Automation (IMSNA), Toronto, ON, Canada, 2013, pp. 1007-1009, doi: 10.1109/IMSNA.2013.6743451.

Chun-Feng Liao, Ching-Ju Cheng, Kung Chen, Chen-Ho Lai, Tien Chiu, and Chi Wu-Lee. Toward a service platform for developing smart contracts on blockchain in bdd and tdd styles. In 2017 IEEE 10th Conference on Service-Oriented Computing and Applications (SOCA), pages 133–140. IEEE, 2017.

Jinliang Xu, Shangguang Wang, Bharat K Bhargava, and Fangchun Yang. A blockchain-enabled trustless crowd-intelligence ecosystem on mobile edge computing. IEEE Transactions on Industrial Informatics, 15(6):3538–3547, 2019.

Zibin Zheng, Shaoan Xie, Hong-Ning Dai, Xiangping Chen, and Huaimin Wang. Blockchain challenges and opportunities: A survey. International journal of web and grid services, 14(4):352–375, 2018.

========== Sorted in Alphabetic order==========\

Abad-Segura, E.; Infante-Moro, A.; González-Zamar, M.-D.; López-Meneses, E. Blockchain Technology for Secure Accounting Management: Research Trends Analysis. Mathematics 2021, 9, 1631. https://doi.org/10.3390/math9141631

A. Kuchimanchi, M. Vagdevi, M. Reddy, G. Avugaddi and S. S. Kumar, "Chatease: A Blockchain based Chat Application," 2023 2nd International Conference on Applied Artificial Intelligence and Computing (ICAAIC), Salem, India, 2023, pp. 1171-1176, doi: 10.1109/ICAAIC56838.2023.10140347.

A. Shahaab, I. Khan, R. Maude and C. Hewage, "A Hybrid Blockchain Implementation to Ensure Data Integrity and Interoperability for Public Service Organisations," 2021, pp. 295-305, doi: 10.1109/Blockchain53845.2021.00047.

Blockchain application and outlook in the banking industry. Finance Innov 2, 24 (2016). https://doi.org/10.1186/s40854-016-0034-9

Chun-Feng Liao, Ching-Ju Cheng, Kung Chen, Chen-Ho Lai, Tien Chiu, and Chi Wu-Lee. Toward a service platform for developing smart contracts on blockchain in bdd and tdd styles. In 2017 IEEE 10th Conference on Service-Oriented Computing and Applications (SOCA), pages 133–140. IEEE, 2017.

D. Čeke, S. Kunosić and N. Buzađija, "Smart Contract execution costs optimisation on blockchain network," 2022 45th Jubilee International Convention on Information, Communication and Electronic Technology (MIPRO), Opatija, Croatia, 2022, pp. 1442-1447, doi: 10.23919/MIPRO55190.2022.9803805.

D. Li, "Study on the Web 2.0-based Internet applications in the university libraries," 2013 2nd International Symposium on Instrumentation and Measurement, Sensor Network and Automation (IMSNA), Toronto, ON, Canada, 2013, pp. 1007-1009, doi: 10.1109/IMSNA.2013.6743451.

Guo, Y., Liang, C. Blockchain application and outlook in the banking industry. Finance Innov 2, 24 (2016). https://doi.org/10.1186/s40854-016-0034-9

Jinliang Xu, Shangguang Wang, Bharat K Bhargava, and Fangchun Yang. A blockchain-enabled trustless crowd-intelligence ecosystem on mobile edge computing. IEEE Transactions on Industrial Informatics, 15(6):3538–3547, 2019.

Karim, S., Rabbani, M.R., & Bawazir, H.S. (2022). Applications of Blockchain Technology in the Finance and Banking Industry Beyond Digital Currencies. Blockchain Technology and Computational Excellence for Society 5.0.

Liu, H.; Yang, B.; Xiong, X.; Zhu, S.; Chen, B.; Tolba, A.; Zhang, X. A Financial Management Platform Based on the Integration of Blockchain and Supply Chain. Sensors 2023, 23, 1497. https://doi.org/10.3390/s23031497

N. A. Thabet and N. Abdelbaki, "Efficient Quering Blockchain Applications," 2021 3rd Novel Intelligent and Leading Emerging Sciences Conference (NILES), Giza, Egypt, 2021, pp. 365-369, doi: 10.1109/NILES53778.2021.9600533.

P. D. Dozier and T. A. Montgomery, "Banking on Blockchain: An Evaluation of Innovation Decision Making," in IEEE Transactions on Engineering Management, vol. 67, no. 4, pp. 1129-1141, Nov. 2020, doi: 10.1109/TEM.2019.2948142.

R. Gupta, V. K. Shukla, S. S. Rao, S. Anwar, P. Sharma and R. Bathla, "Enhancing Privacy through “Smart Contract” using Blockchain-based Dynamic Access Control," 2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM), Dubai, United Arab Emirates, 2020, pp. 338-343, doi: 10.1109/ICCAKM46823.2020.9051521.

U. K. Shakila and S. Sultana, "A Decentralized Marketplace Application based on Ethereum Smart Contract," 2021 pp. 1-5, doi: 10.1109/ICCIT54785.2021.9689879.

W. Zhou and M. Sun, "Accounting Cyber Security Based on Blockchain," 2022 IEEE Asia-Pacific Conference on Image Processing, Electronics and Computers (IPEC), Dalian, China, 2022, pp. 1254-1257, doi: 10.1109/IPEC54454.2022.9777549.

Zibin Zheng, Shaoan Xie, Hong-Ning Dai, Xiangping Chen, and Huaimin Wang. Blockchain challenges and opportunities: A survey. International journal of web and grid services, 14(4):352–375, 2018.