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RESEARCH ARTICLE

A Blockchain-Based Crowdsourcing Loan Platform for Funding Higher Education in Developing Countries

KWAME OMONO ASAMOAH[1,2], **ADJEI PETER DARKO**[3], **COLLINS OPOKU ANTWI**[4], **SETH LARWEH KODJIKU**[5], **ESTHER STACY E. B. AGGREY**[6], **QING WANG**[2,7], **AND JIA ZHU**[2,7]

[1]School of Education, Zhejiang Normal University, Jinhua, Zhejiang 321004, China
[2]Key Laboratory of Intelligent Education Technology and Application of Zhejiang Province, Zhejiang Normal University, Jinhua, Zhejiang 321004, China
[3]School of Psychology, Zhejiang Normal University, Jinhua, Zhejiang 321004, China
[4]College of Geography and Environmental Science, Zhejiang Normal University, Jinhua, Zhejiang 321004, China
[5]School of Computer and Information Engineering, Zhejiang Gongshang University, Jianggan, Hangzhou 310018, China
[6]School of Computer Science and Engineering, University of Electronic Science and Technology of China, Chengdu 610054, China
[7]School of Computer Science and Technology, Zhejiang Normal University, Jinhua, Zhejiang 321004, China

Corresponding author: Jia Zhu (jiazhu@zjnu.edu.cn)

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ABSTRACT In developing countries, funding is a significant obstacle to receiving higher education. Brilliant but needy students cannot complete their studies since their parents are unemployed and their countries' economies are poor. As a result, the students' talents are not harnessed to their full potential. In order to help students obtain higher education and harness their full potential, governments provide student loans to students in higher education. The government provides loans to students through the ministry of education. The students pay back the loan with interest when they start working. Governments have been the sole funders of student loans. The emergence of COVID-19 and the Russia-Ukraine war have resulted in a global economic crisis. Because of the global economic crisis, the government's spending has increased. In order to help reduce the burden of government and thereby reduce spending, we intend to revolutionize the student loan program through blockchain and crowdsourcing. This work presents a blockchain-based crowdsourcing decentralized loan platform where investors will be brought on board to provide funds for students in higher education. The platform will allow students to apply for loans from investors through registered financial institutions. The students will pay back the loans with interest when they enter the workforce. The proposed platform will allow students to fund their education, investors will get interest on the money they invest, and governments can channel the money they put into student loan programs into other avenues. We perform a thorough security analysis and back the efficiency of our work with numerical results.

INDEX TERMS Blockchain, crowdsourcing, higher education, smart contracts, student loans.

I. INTRODUCTION

University students have many obstacles to overcome to achieve their best academic results [1]. To complete an educational programme effectively, much more is required than just studying. Many things can hinder a student's academic success, like not managing their time well, having money problems, not getting enough sleep, social events, and, for some students, taking care of their families. Funding is a significant obstacle to obtaining a higher degree in developing countries. Brilliant but needy students cannot continue their education to the tertiary level because their parents do not have jobs and their countries' economies are bad. Therefore, these brilliant but needy students' talents are not used to their full potential [2].

Student Loan Schemes have been set up in developing countries to help college students pay for their programmes and repay the loans when they start working and making

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money [3]. The sole contributor to the scheme has been the governments in these developing countries through the Ministry of Education. The Students Loan Scheme allows students accepted into and studying recognized programmes at higher universities to get loans to help pay for their education. For example, in Ghana, the Students' Loan Scheme was introduced under PNDC Law 276 in 1989 [4]. Students apply for this loan through the Ministry of Education (GES) and pay it back with interest when they start working after graduating.

The emergence of COVID-19 and the Russian-Ukraine war has triggered a global economic crisis [5], particularly in developing countries. Economic growth in developing countries is subject to significant fluctuations such as high inflation, a lot of state debt, and significant changes in foreign direct investment, all of which hurt the country's economy. The economic crisis has pressured governments to provide social interventions for their citizens in addition to those already offered, such as free senior high school, national health insurance schemes, student loans, etc [6]. To help ease the burden on the government, specific social interventions, such as the Students' Loan Scheme, can be made public through blockchain-based crowdsourcing to invite investors to invest in them.

Crowdsourcing is a method for decentralized problem-solving based on an open call for remedies [7]. A typical crowdsourcing platform comprises three responsibilities: requestors, workers, and a centralized crowdsourcing unit. Through the crowdsourcing platform, requesters send tasks difficult for machines but simple for humans to complete [8]. Workers willing to solve the task start competing and sending answers to the crowdsourcing platform. Requesters then choose a good solution (usually the best one that gets the job done) and give incentives to the workers who offer it.

A blockchain is a distributed ledger of all peer-to-peer network transactions. A blockchain allows involved parties to validate transactions without the involvement of a centralized entity [9]. Possible uses include money transfers, trade settlements, voting, and many other problems. This work revolutionizes the Students Loan Scheme in developing countries through blockchain-based crowdsourcing. This work aims to present a blockchain-based decentralized crowdsourcing framework for higher education student loan programs that address the positive effects on college students, academic institutions, and possible investors.

This platform will allow students (requesters) to apply for funding through registered financial institutions (miners). Investors (workers) who put money into this plan will get their money back in full, plus a percentage of the student's earnings after being out of school for a certain amount of time. The method uses the blockchain's benefits as a distributed architecture that provides a reliable long-term investment mechanism, authenticity, and accountability to create a trusted funding platform for poor college students who want to continue their education. Using blockchain, the investors and students can be monitored to ensure the data is correct since it is part of the chain that has already been checked because the system is distributed. The contributions of this paper are as follows:

- This article identifies the challenges that brilliant but needy students face in obtaining higher education in developing countries.
- A design of a blockchain-based decentralized crowdsourcing platform that allows students to raise funds for their education and pay later when they start working is presented. This can be done by establishing a law with the country's finance ministry to track these students as soon as they enter higher education. When the students start working after school, a portion of their salary can be deducted and given to the fundraiser, who can then give it to the corresponding investor. The deduction is made monthly until the student finishes paying for the loan.
- The investment protocol in this article is automated with smart contracts. The smart contracts bind the students on the system to their investors. The investments made on the system are liquid assets that can be changed to tokens at any time.
- A performance analysis is provided to demonstrate the effectiveness of our proposed system.

The remainder of this paper is organized as follows: Section II describes the tools employed in this work. Section III reviews related works to this study, while Section IV describes the system model. Security and performance analysis are presented in section V, and section VI concludes the work.

II. PRELIMINARIES

This part presents the various technologies employed in the blockchain-based crowdsourcing platform. Furthermore, this section concisely describes blockchain technology, a crowdsourcing platform, and smart contract.

A. CROWDSOURCING

Crowdsourcing is outsourcing tasks to a large group of individuals through a public request for contributions [7]. In crowdsourcing, a group called requesters sends jobs to a crowdsourcing system, and a second group called workers contributes to the task's completion. The outcome of completing a task is referred to as an output. When requesters entrust quality control duties to the crowdsourcing platform, outputs can be evaluated and compensated directly and spontaneously by the crowdsourcing system. The compensation can be monetary, material, or reputational [10].

In principle, there are two different kinds of platforms for crowdsourcing: (1) a hiring method in which workers apply for specific tasks. Following the completion of the application procedure, the requester who posted the task selects workers from the pool of applicants to complete the assignment. The number of workers required varies depending on

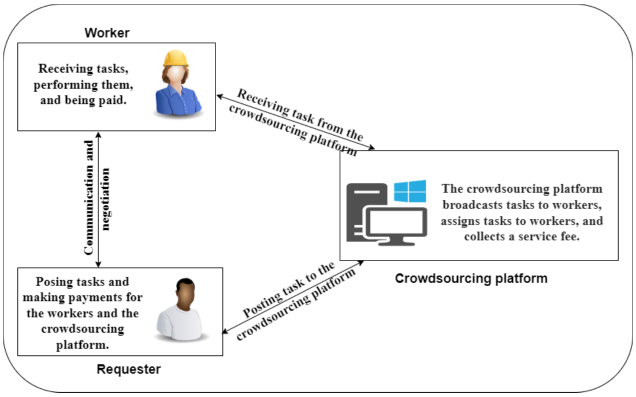

FIGURE 1. A model of a typical crowdsourcing platform.

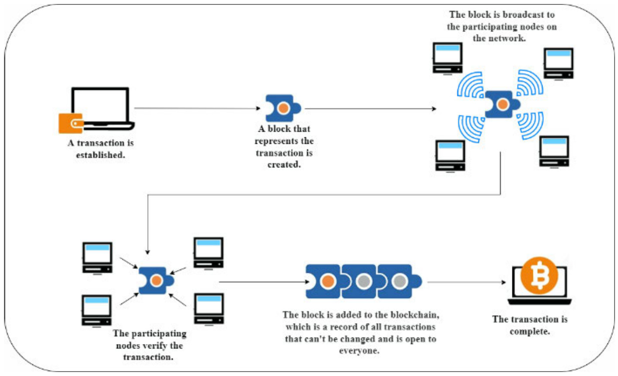

FIGURE 2. A working principle of blockchain technology.

the requester. Only the chosen workers are qualified for the incentive upon completing the task. (2) competition-based platform in which workers have no initial choice. There is no limit to the number of workers who can perform a task. However, the reward is given to the best submission, as determined by the requester [11]. Figure 1 shows the different entities of a typical crowdsourcing platform and how they work together.

Crowdsourcing helps organizations outsource work to individuals in any part of the world. So, crowdsourcing lets organizations get a lot of knowledge and skills without paying for full-time employees. Crowdsourcing is growing into a more common approach for funding special projects. As an alternative to traditional ways of getting money, crowdsourcing uses the shared interests of a group to raise money without the need for traditional gatekeepers and middlemen.

B. BLOCKCHAIN TECHNOLOGY

A blockchain is a distributed ledger of all peer-to-peer network transactions [9]. With this technology, participants can confirm transactions without a central clearing authority. The method is designed to timestamp digital documents so that they cannot be altered or backdated. Blockchain aims to address the double-records issue without requiring a centralized system. The blockchain enables the security and confidentiality of items such as money, assets, and contractual arrangements without needing a third-party such as a government or a bank.

Once data is stored on a blockchain, it is nearly impossible to alter it. It is easy to understand the working principles of blockchain technology by comparing them to a Google Docs file. A Google Doc is not duplicated or transmitted whenever it is shared with a number of people; rather, it is simply distributed. Consequently, a decentralized, distributed network is created, enabling everyone to access the basic file simultaneously. All changes to the file are logged in real-time, making them completely visible and ensuring that no one is locked out while awaiting modifications from other parties. One thing to note is that, unlike Google Docs, it cannot be altered after writing data to the blockchain, increasing its security level. Figure 2 depicts how the blockchain works. In a nutshell, the blockchain is a decentralized, distributed (public or private) ledger of various types of transactions organized in a peer-to-peer (P2P) network [12]. This network is comprised of numerous computers in such a manner that the data cannot be modified without the consensus of the entire network.

C. SMART CONTRACTS

Smart contracts are blockchain-based applications that execute when specific conditions are met [13]. The contract's code and negotiations are disseminated across a decentralized blockchain network. The code controls the execution of transactions, which are easy to trace and immutable. Smart contracts enable trusted transactions and agreements between different, unknown participants without requiring a central body, legal system, or external enforcement agency. Most of the time, they are used to keep track of how terms and conditions are being followed so that everyone knows the outcome right away, without the need for a third party or wasted time. They can also automate a workflow by automatically making the next step happen when certain conditions are met.

Smart contracts are built on top of the blockchain, and the terms and conditions that have been authorized are transformed into executable computer programs [14]. The logical linkages between the terms and conditions are likewise kept as logical flows in computer programs (e.g., the if-else-if statement). Each contract statement's execution is recorded as an irreversible transaction on the blockchain [15]. Smart contracts ensure proper access management and compliance. Specifically, programmers can provide access authorization for each contract method. As soon as any criteria in a smart contract are met, the activated statement will perform the related function in a specified way [16]. For instance, Alice and Bob agree on the punishment for contract violation. If Bob violates the contract, the appropriate punishment (as mentioned in the contract) will be taken from his deposit.

III. LITERATURE REVIEW

Due to their promising features, crowdsourcing and blockchain have been used in several domains, such as software engineering, healthcare, marketing, computer vision, government, education, etc. This part reviews some blockchain-based crowdsourcing frameworks in the literature.

Kamali et al. [17]. presented a blockchain-based method for spatial crowdsourcing in which workers approve or disapprove of the accuracy of tasks. Tasks that include a type and location are uploaded to the system by requesters. In the proposed system, all involved participants receive compensation. The system considers both spatial and non-spatial incentive factors to encourage people to work together to collect accurate spatial data. To promote student participation in higher education, Horta et al. [18] presented a study on crowdfunding in higher education and suggested that crowdfunding is a plausible method of obtaining financial assistance for learning activities to supplement funding from other sources. However, the authors voiced concern regarding crowdfunding as a burden on academics and students to search for resources for their educational experiences that academic institutions should make available.

In [19] BitFund global crowdfunding platform was proposed. In the system, investors and developers serve as network nodes. The investors can ask for a specific project and submit their opening offer value regarding time, cost, and maintenance needs. Several developers may submit bids with varying values for the same project parameters to be awarded the project. The developers participate in numerous rounds of bidding till the optimal solution is attained. A smart contract is implemented to ensure the investors get the best solution. Rashid et al. [20] proposed a blockchain-based platform that provided sponsorship for students in higher education. Investors provided the sponsorship in many ways, such as through scholarships, donations, loans, etc. A group of competing agents raises funds and organizes and maintains them.

In 2019, Li and Han [21] proposed a work demonstrating the educational utility of blockchain. Students' records were stored using blockchain technology. The blockchain's purpose was to ensure that the information was safe and trustworthy. Further, data was shared using smart contracts. The evaluation of the work centered on demonstrating that the solution presented was secure and computationally efficient. certificates. The solution presented to handle the sharing of certificates relied on a key provided to the graduate. The students were fully accountable for the key's security. The suggested method's primary objective is to be economically sustainable and cost-effective. In [22], research was conducted on how college students' crowdfunding websites for business projects have changed over time. The goal of this work was to address the practical needs of crowdfunding in China. Hip-crowdfunding services can increase the number of people who visit the website and give existing customers high-quality service.

Most of the aforementioned research in higher education relies on confined concepts and rarely discusses specifics. Some of the associated research is offered only to a selected group of entities. In contrast, the idea described in this work tries to include people and groups from all over the world who are interested in the plan. It is, therefore, open to the cooperation and inclusion of individuals and organizations worldwide.

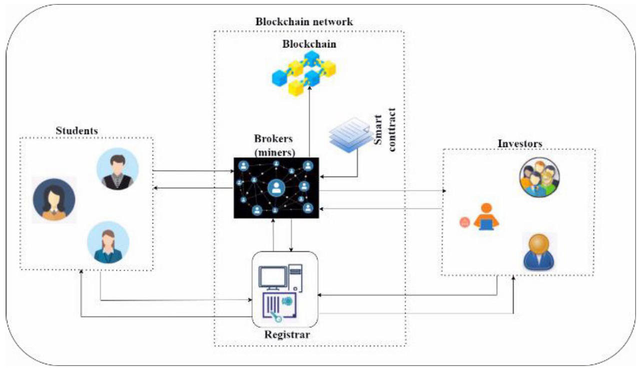

FIGURE 3. System architecture.

IV. SYSTEM MODEL

This section gives a description of the system architecture of the blockchain-based crowdsourcing platform for providing funds for tertiary education students in developing countries. A brief description of the various entities employed in the system is presented. The system architecture is shown in Figure 3.

A. SYSTEM COMPONENTS

1) STUDENTS

Students seek financial assistance for their higher education through study loans. If the students are given loans, they must repay them according to the terms and conditions. Students interested in the system must first sign up for the platform through the registrar. After successful registration, they are added to the blockchain network. A student on the platform is represented as $S_i = \left\{sid, loc, schName, natID, KS_i^{pk}, KS_i^{sk}, KS_i^{ad}, KG_i^{ad}, t_{reg}\right\}$ where:

- sid is the ID of the student.
- loc is the location of the student.
- $schName$ is the name of the school that the student attends.
- $natID$ is the student's national ID.
- KS_i^{pk} is the public key.
- KS_i^{sk} is the secret key.
- KS_i^{ad} is the wallet address of the student.
- KG_i^{ad} is the wallet address of the guarantor.
- t_{reg} is the time of registration of the student.

It should be noted that students are the loan requesters on this platform, so the terms students and loan requesters will be used synonymously.

2) BROKERS (MINERS)

The brokers are registered businesses that act as independent third-party agencies to raise funds for students and then maintain their records. The brokers act as representatives for the students and bring investors on board on their behalf. When the total amount required by a student has been raised, the brokers also serve as miners and create a contract between the student and the investors. The brokers are very important because they verify, approve, and keep the information and applications of students safe. A broker on the system is denoted as $B_j = \left\{bid, busid, busName, loc, KB_j^{pk}, KB_j^{sk}, t_{reg}\right\}$, where:

- bid is the ID of the broker.
- $busid$ is the business identification number of the broker.
- $busName$ is the registered business name of the broker.
- loc is the location of the business.
- KB_j^{pk} is the public key of the broker.
- KB_j^{sk} is the secret key of the broker.
- t_{reg} is the time of registration of the broker.

Brokers serve as the miners on the platform, so the terms brokers and miners will be used interchangeably.

3) INVESTORS

The investors comprise individuals or businesses in different parts of the world dedicated to funding higher education through fundraising events. Each investor is given a virtual wallet, and the balance is adjusted based on the investor's dedication to sponsoring a particular student. An investor on the system is denoted as, $IN_m = \left\{inid, natID, loc, KIN_m^{pk}, KIN_m^{sk}, KIN_m^{ad}, t_{reg}\right\}$, where:

- $inid$ is the ID of the investor.
- $natID$ is the national identification number of the investor.
- loc is the location of the investor.
- KIN_m^{pk} is the secret key of the investor.
- KIN_m^{sk} is the secret key of the investor.
- KIN_m^{ad} is the wallet address of the investor.
- t_{reg} is the time of registration of the investor.

4) REGISTRAR

The registrar is a trusted server that generates keys, signatures, and certificates for all the system entities. It is a crucial entity on the network because no other entity in the system is allowed to perform these actions. Each entity on the system receives encryption keys and signatures from the registrar. The registrar also performs credential validation.

5) LOAN REQUEST

A student S_i requests a loan on our blockchain-based crowdsourcing platform by posting a request. This request is termed a loan request, denoted as $LR_{S_i} = \{LR_{id}, sid, le, G_{id}, amnt_{requested}, t_{needed}, t_{crt}\}$

- LR_{id} is the loan request ID.
- sid is the ID of the student.
- le is the level of study of the student.
- G_{id} is the guarantor's ID.
- $amt_{requested}$ is the amount of money needed by the student.
- t_{needed} is the time the student needs the loan.
- t_{crt} is the time of the creation of the request.
- sid is the unique ID of the student who sent the request.
- $inid$ is the unique ID of the investor who funded the request.

6) CROWDSOURCING PLATFORM

This is a platform that links the various actors in the system together, denoted as *CSP* The platform that allows the brokers to receive loan requests from the students. The brokers then look for investors willing to provide funds for the students.

7) BLOCKCHAIN

A blockchain is a decentralized transaction ledger that uses a chain to store a group of blocks. A block in our suggested architecture holds details about a loan that has been completed and includes them in the blockchain network. A block is denoted as

$$BCN = \{bcnid_n, bcnid_{n-1}, bcnt_n, cspr, sid, inid\}$$

- $bcnid_n$ is the unique ID of the block. The block's hash value is used as the block ID.
- $bcnid_{n-1}$ denotes the previous block. The hash value of the preceding block is used as the prior block's ID.
- $bcnt_n$ is the time of creation of the block.
- $cspr$ is the crowdsource loan request.

8) SMART CONTRACT

A contract with predefined contractual terms written by the blockchain network is called a smart contract. A smart contract in our system is represented as, $sct = \{sctid, cspr, sid, inid, sctpt, sctac\}$.

- $sctid$ is the unique smart contract ID for the loan request.
- $cspr$ is the crowdsource loan request.
- sid is the unique ID of the student who sent the request.
- $inid$ is the unique ID of the investor who funded the request.
- $sctpt$ is the terms and conditions used to create the smart contract.
- $sctac$ is the account balance of the smart contract.

B. USER REGISTRATION

The crowdsourced platform is mostly operable by approved users. A user must first sign up for the platform using a smart device. After completing registration, the crowdsourced platform will issue the user with a unique user identifier (User ID). Nevertheless, some users may turn malicious and try to get around the system by making up false user identities, as in the Sybil attack. In a Sybil attack, a single node runs many active fake identities (called "Sybil identities") simultaneously in a peer-to-peer network. This attack is meant to weaken the authority or power of a well-known system by taking over most of the network's power.

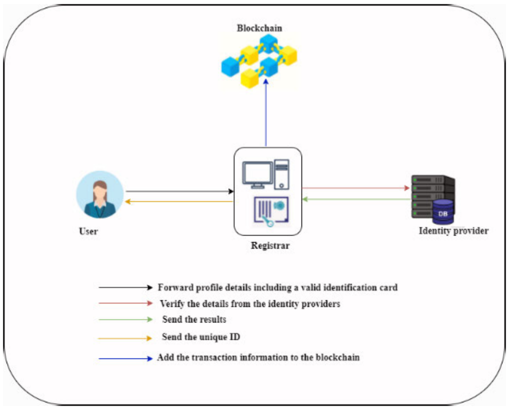

FIGURE 4. **Registration of system users.**

One of the most prevalent methods for avoiding this intrusion is to collect a nonrefundable deposit from the user during registration. But, this will increase the cost for the user because most of the system beneficiaries are students, and they may be hesitant to pay the registration fee, thereby decreasing the number of system users. Therefore, the user must present any valid form of identification such as student ID, office ID, national ID, passport, or driver's license to verify his or her identity. This allows us to protect the platform against a Sybil attack.

The user registration process is depicted in Figure 4. The user will first forward to the crowdsourcing platform his or her profile details, which must include a valid identification card. The registrar receives and verifies the information from the identity providers, such as the passport office, driver and vehicle licensing authorities, etc. If the user identification is genuine, the crowdsourced platform will create a unique ID for the user and add the user to the system users. System users are organized according to the role they play in the system (i.e., students, brokers, and investors). This classification will assist the platform in the selection of invesors to fund the students.

C. ACQUISITION OF TOKENS ON THE PLATFORM

Tokens are bought either from the platform or from other users. To purchase tokens from the platform, a user just has to quote the number of tokens he or she wants to purchase and provide the equivalent in Ether to the platform. System users can also sell their tokens to other system users. In managing the buying and selling of tokens on the platform, a smart contract transfers the tokens from the seller's wallet address to the buyer's wallet address. The transaction can take place only if the buyer has a sufficient amount of Ether and the seller has enough tokens in her wallet. When these terms are met, the Ether is transferred to the seller's account, and the tokens are transferred to the buyer's wallet.

Because the price of certain tokens used as collateral rises when a loan is increased, the platform and token holders will incur different costs. As a result of this, there will be irregularities in the price of the tokens. Mapping data structures from the Solidity programming language addresses the inconsistencies in token pricing. This takes as arguments the contract address and the variation in the price of the tokens. After giving the mapping structure an Ethereum address and a price variation, it returns the number of tokens in the address for that specific price.

The decision to purchase tokens from the smart contract platform or other system users depends on the buyer. The platform allows the smart contract to purchase tokens from the users, which depends on the availability of the money raised from selling the tokens. When users buy tokens from the platform to keep the fund going, they can get 10% less Ether than the original price.

D. TERMS AND CONDITIONS OF THE LOAN SCHEME

For investors not to lose too much money if the loan requester doesn't pay it back, they must agree to the rules of the loan scheme listed on the platform.

- The person who wants to borrow money must have a guarantor who can put up tokens worth 80\% of the amount he or she wants to borrow.
- 0.5% daily interest on the loaned amount. This rate can be modified using the smart contract, and the periodicity can be changed from daily to monthly.
- A daily increase of 0.5% is applied to the collateral price. Additionally, this rate and structure of increase are modifiable.

E. COMMUNICATION DESIGN

This part presents the communication flow of the proposed platform. Users (students and investors) who want to be part of the system first send a registration request to the platform, and the registrar receives this on the platform. The registrar acknowledges the reception of the request. After that, the registrar generates the users' credentials, including cryptographic keys and a unique identity. The registrar sends the credentials to the corresponding user and sends a copy to the blockchain network for storage on the blockchain. When users get their credentials, they join the platform and can make a request.

A student requesting a loan sends a loan application to the blockchain network (a network of brokers). The brokers pick up the request to raise funds for the loan from the available investors on the platform. The broker who raises the required amount first wins and manages that transaction. The broker will become the transaction's miner and earn a reward. After the broker finds a suitable investor on the platform, the request is sent to the corresponding investor for review. The investor agrees, and a notification is sent to the broker on the platform. If, on the other hand, the investor rejects the request, the broker will have to initiate the process to find another investor. The broker then prepares the contract that binds the student and the

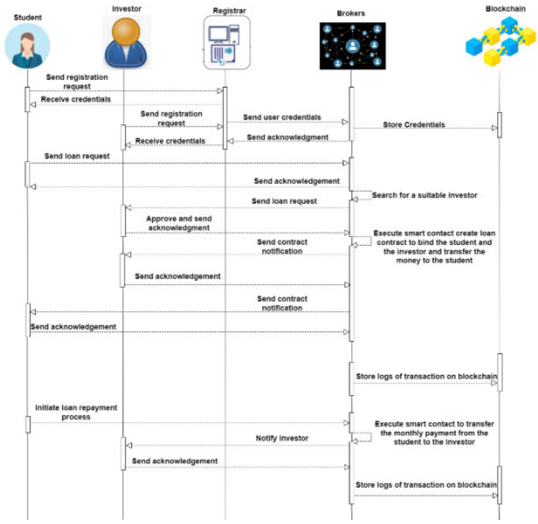

FIGURE 5. The communication flow between the system components.

investor and notifies the parties involved. The parties send an acknowledgement to the broker. The money is then sent to the student, and the transaction logs are stored on the blockchain.

When a student enters the workforce, he or she starts repaying the loan. By then, the accumulated interest would have been calculated and added to the principal amount. The broker managing the transaction executes a smart contract to deduct a portion of the student's monthly salary based on conditions stated in the contract. The deduction is done monthly until the student finishes paying the loan amount. The communication process is depicted in Figure 5.

F. SUBMISSION OF LOAN REQUEST

The loan requesters could submit a loan request to the crowd-sourced platform regardless of time or location. Nevertheless, to submit a loan request, the requester sends an encrypted message explaining the loan request in sufficient detail for the platform. This explanation is important as it helps brokers easily discover potential investors. The preceding section formalizes the definition of a loan request.

Algorithm 1 depicts the process of submitting a loan request on the blockchain-based crowdsourcing platform. The requester ID is checked initially to ascertain whether it is registered on the platform. If the ID is not valid, the request is rejected. On the other hand, if the ID is valid, another check is conducted to see if there are enough tokens in the wallet of the guarantor as stated in the terms and conditions. If there are not enough tokens in the wallet of the guarantor, the request will be rejected. If there are enough tokens, the algorithm checks whether investors are ready to fund the student. If there are no investors at the time of the application, the requestor is notified that there are no investors and is put on a waiting list. In the case where there are investors, the amount needed, the time needed, and the time of the creation of the request are

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Algorithm 1 Loan Request Submission

Input: $\left\{sid, KG_i^{ad}, amnt_{requested}, t_{needed}, t_{crt}\right\}$
Output: LR_{id}
Check whether sid is a valid ID
if sid is valid **then**
  if $KG_i^{ad}\, amount \geq 0.8 * amnt_{requested}$ **then**
    $availInvestor = checkAvailableInvestor()$
    if $availInvestor > 0$ **then**
      Record $amt_{requested}$
      Record t_{needed}
      Record t_{crt}
      Create loan request (LR_{S_i}) with a unique ID
      LR_{id}
    add LR_{id} to β
  else
    "No available investor at this time"
  end if
else
  "Guarantor's reputation is not accepted"
end if
else
  return "Loan request placement was rejected"
end if
return "Loan request created successfully with ID LR_{id}"

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recorded, and the loan request is created with a unique ID. The list of loan requests is updated, and a success message, including the loan request ID, is sent to the corresponding student.

G. SMART CONTRACT DESIGN

An investor may fund a student in whole or in part through single or several brokers. The broker who secures the total amount first will have the chance to draft the contract between the loan requester and the investor(s). The winner will also be allowed to handle the loan requester's profile. After acquiring the student, the broker will generate a transaction, store it in a new block, and add the block to the chain upon reaching a consensus. The loan request will after that be dropped from the loan request table (β).

1) INVESTOR SELECTION

Users must meet a number of requirements before they can become investors on the platform. Algorithm 2 shows how investors are chosen to give money for loan requests on the platform, and the brokers execute it.

First, the algorithm checks whether there are available investors on the platform. If there are investors, it proceeds to check which investors have enough tokens to fund the student. The first investor with enough tokens is chosen, and the corresponding ID (*inid)* is appended to the loan request ID LR_{id} to indicate that LR_{id} is being funded by *inid.*

Algorithm 2 Investor Selection

Input: {List of requests in the loan request table (LRT), List Of Investors (λ)}
Output: $inid_{LR_{id}}$
for all LR_{id} in LRT **do**
$availInvestor = checkAvailableInvestor(\lambda)$
  for all $inid$ in $availInvestor$ **do**
 if $LR_{id}.amnt_{requested} \leq IN_i.amnt_{requested}$
    $inid.LR_{id}$
    break
   else
     continue
   end if
   remove LR_{id} from LRT
  end for
end for
return $inid.LR_{id}$

2) SIGNING OF CONTRACT AND TRANSFER OF THE LOAN TO THE REQUESTER

A smart contract is between the loan requester (i.e., the student) and the investor. The contract is executed automatically once the specified terms and conditions are met. The crowdsourcing platform will start the smart contract for loan requesters and investors.

Algorithm 3 Signing of Contract

Input: $\left\{sid, KS_i^{ad}, inid, KIN_m^{ad}, bid\right\}$
Output: $\{signedContract\}$
$loanMoney = ReceivedMoney\left(inid, KS_i^{ad}\right)$
$signedContract = SignContract\,(sid, inid, bid)$
if $VerifiedResult(signContract)$ **then**
  $TransferMoney\left(sid, KS_i^{ad}\right)$
  return $signedContract$
else
 $TransferMoney\left(inid, KIN_m^{ad}\right)$
 return "Incomplete loan request message"
end if

First, the crowdsourcing platform receives the loan money from the investor. Algorithm 3 shows the process of signing the contract between the student and the investor. The platform then creates a smart contract for the loan amount based on the terms and conditions. The loan requester, investor, and broker will sign the contract to complete the loan request utilizing the singContract function. After receiving the contract results from the parties involved, the contract is validated using the verifyContract function. If the results are verified successfully, the money is transferred into the wallet of the loan requester. On the other hand, if the verification fails, the money is transferred back to the investor's wallet.

3) REPAYING THE LOANED AMOUNT

As soon as a loan request transaction is done, it will be sent out to the whole platform and stored in the block that goes with it. The loan's smart contract will always monitor the loan's terms and conditions, such as the date of payment set up during the loan request transaction, and send a notification to remind the requester on a time-to-time basis. At the time of payment, the requester initiates the repayment request. The smart contract calculates the accumulated interest and adds it to the principal amount as γ using the *retrieveAmountDueForPayment()*. This becomes the total amount the loan requester will pay. This can be paid on a monthly basis or at a goal depending on the capacity of the requester. The algorithm for repayment of the loan is depicted in Algorithm 4.

Algorithm 4 Repayment of Loan

Input: $\left\{sid, KS_i^{ad}, inid, KIN_m^{ad}, \omega\right\}$
Output: $\left\{amountLeft/\text{``}Loanhasbeenpaidinfull''\right\}$
$\omega \leftarrow receiveMoney\left(sid, KS_i^{ad}\right)$
$\gamma \leftarrow retrieveAmountDueForPayment\,(sid)$
if $\gamma > 0$ **then**
  $TransferMoney\left(inid, KIN_m^{ad}, \omega\right)$
  $amountLeft = \gamma - \omega$
  return $amountLeft$
else
  $TransferMoney\left(sid, KS_i^{ad}\right)$
  return "Loan has been paid in full"
end if

The crowdsourcing platform receives the amount the loan requester wants to pay after initiating the repayment request. The smart contract algorithm for repayment of the loan is executed. First, the algorithm receives the money from the requester as ω. Then the total amount due for payment is retrieved as γ. If the amount due for payment is greater than zero, then the received amount ω is transferred to the investor's wallet. Otherwise, the amount received is transferred back to the requester. This algorithm is executed monthly until the requester finishes paying for the loan.

H. CONSENSUS BUILDING PROCESS

Authorized brokers and a leader administer the consensus process. The leader is the broker, who provides the first proof of work. The leader broadcasts block data, a timestamp, and proof-of-work to other permitted brokers for validation and auditing, as shown in Figure 6. For collaborative supervision and validation, these miners check the data in each block and share their digital signatures and the results of their checks.

Every miner compares its audited results to those obtained by others and submits a response to the leader after getting the audited results. This response comprises the miner's

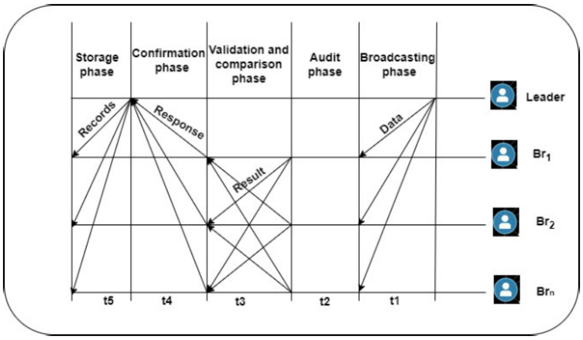

FIGURE 6. The process of carrying consensus on the blockchain network.

audited result, compared result, and audited result record signatures. The leader evaluates the responses from the miners.

If all the miners agree on the block's content under consideration, the leader will reply to all permitted miners with the records containing the current audited block content and the associated signature for storage. This block is then added to the blockchain, and the leader is awarded. If, on the other hand, some miners disagree with the block content, the leader will evaluate the outcome of the auditing and, if appropriate, send the block content to these miners for a second audit.

I. SUMMARY OF THE LOAN REQUEST PROCESS

- A student S_i who wants a loan, posts a loan request LR_{Si} on the platform. The request is broadcast on the blockchain-based crowdsourcing platform.
- The application is then picked up and processed by a broker on the platform. The broker searches for a suitable investor to sponsor the student. When a suitable investor is found, the loan request is sent to the investor.
- When an investor accepts to sponsor the student, he or she notifies the platform with an acknowledgement message.
- The corresponding broker executes the smart contract upon receiving the acknowledgement from the investor. The smart contract will be created based on the request.
- The terms and conditions of the contract are communicated to the student and the investor. The investor prepares the amount involved in his wallet after agreeing to the terms and conditions of the contract. The investor then sends a message to the corresponding broker on the platform.
- After receiving the message, the broker triggers the smart contract, and the smart contract transfers the money to the student's wallet.
- The broker then creates a block out of the transaction, which is added to the blockchain upon consensus, completing the mining process. The corresponding broker gets a reward for mining the block.

V. SECURITY AND PERFORMANCE ANALYSIS OF THE PROPOSED SYSTEM

This section presents a security analysis of the proposed blockchain-based crowdsourcing loan platform. An evaluation of the system performance is further presented.

A. SECURITY ANALYSIS

The blockchain-based crowdsourcing platform employs a private blockchain to provide security and privacy protection for loan requests. Listed below are the blockchain-related security results.

1) PRIVACY

For large-scale implementation and acceptance of crowdsourcing platforms, both task requesters and contributors must consider privacy issues. In the proposed platform, as loan requesters and investors sign up for the system, they are given a unique identifier, which provides anonymity and privacy for requesters and investors. The system users are given cryptographic keys that are used to encrypt transactional messages before sending them on the platform.

2) TRANSACTION AUTHENTICATION

Transactional data is publicly checked and verified by all brokers. Due to the high cost, it is impossible to compromise all brokers on the platform. When a broker is compromised, a block with a mistake will be found and fixed before forming the block.

3) CONCUSSION

A concussion issue can occur with decentralized systems, especially blockchain-based systems. This issue occurs when multiple miners attempt to create a block simultaneously. In this step, each miner selects the same block's hash as a parent hash and generates a block. These blocks are not permitted on the blockchain system. The proposed platform eliminates concussions by managing all loan-related transactions in smart contracts. Consequently, each block's information will be sent to the miner following a predetermined time interval.

4) DATA UNFORGEABILITY

The blockchain network is decentralized, and all transactions are cryptographically signed. This makes it impossible for an attacker to pose as a system user and break into the network. This is because an attacker cannot forge the digital signature of any broker (miner) or take possession of the more significant part of the platform's resources. Encrypted with the system's keys, an attacker who controls one or more brokers in the blockchain network cannot discover anything about the actual data. The attacker cannot falsify the saved and validated data in the blockchain.

TABLE 1. Symbols and meanings.

Symbol	Meaning
λ	List of investors
γ	Total amount due for payment
ω	Money received from the requester
β	Loan request table

5) SHARING THE CONTRACT INFORMATION

When matching the students and the investors, the details are compiled into a file and transmitted to the corresponding student and investor(s) through the email address they signed up with for reference purposes. NB: The file hash is also saved in the block, similar to the conventional legal document signed by the parties. The broker generates it after mining. It contains information such as the program cost, program duration, student and respective investors, the amount each investor contributed, and rewards to the investors after the student obtains employment.

6) MODIFYING BLOCK CONTENT

If a miner adds a block to the chain, it is impossible to modify it. Nevertheless, if updating a student or investor's information becomes necessary, a copy of the old block is retrieved, modified as appropriate, and included in the chain as a new block. The modification does not affect the previous block and remains as it was. It should be noted that only student and investor information, such as contact and address information, may be modified in the new coalition; the agreement in the contract is unchangeable.

7) DECENTRALIZATION

The blockchain is a decentralized and distributed ledger network comprising interconnected nodes. All the nodes in the network receive a shared ledger that contains the blockchain's transaction records. Unlike traditional systems that use crowdsourcing frameworks, the presented system ensures that the records of students and investors are saved on the blockchain.

8) SECURITY OF THE INVESTED MONEY

Students and their guarantors register on the platform with their national identification numbers linked to their bank accounts. The national identification number is used to track the students and guarantors when it takes too long for the student to start the repayment process. If the student takes too long to start the repayment process, the repayment algorithm will be run on the guarantor's account. If the guarantor fails to pay for the loan, the tokens used as collateral will be seized.

TABLE 2. Comparison between our proposed system and other related systems.

Metric	[23]	[24]	[25]	Ours
Decentralization	NO	YES	YES	YES
Integrity	YES	NO	NO	YES
Privacy	YES	YES	YES	YES
Security	YES	YES	YES	YES
Concuss	YES	YES	YES	NO
Anonymity	YES	YES	YES	YES

B. COMPARATIVE ANALYSIS

The result of a comparison between our work and that of other systems, based on the measurements examined, is displayed in Table 2 . Table 2 shows that decentralized and concussion were not achieved in [23], whilst integrity and concussion were not achieved in [24] and [25]. But in the proposed system, all the metrics considered were achieved.

C. PERFORMANCE ANALYSIS

This part gives a simulation of the blockchain-based crowdsourcing loan platform. Some simulations were conducted to illustrate the communication and interaction between the system users during transaction operations. In the simulation, the retrieval and execution of transactions on the blockchain-based crowdsourcing loan platform are evaluated for efficiency.

The platform's effectiveness is analyzed by establishing node connections to various entities over an Ethereum network utilizing proof of work consensus protocol. The simulation was performed on a computer with an Intel i7 processor and 16 GB of memory. The simulation of the blockchain was done with Ubuntu 16.04.7 LTS operating system. A 5-time experiment, described as an "epoch," is executed on the Ethereum Ropsten network, which communicates in real-time with more than 5000 nodes on the blockchain network. For analysis of the confirmation times of transactions, the cost of a transaction per epoch is increased over the epochs. On BitChart, the hash rate of the simulation was 292,681.22 GH/s, with a complexity of 3,603.97 TH and a block time of 13.8 seconds. A smart contract was implemented with a cost of 0.00364711295192 Ether on Metamask and a gas charge of 523102 Wei authenticating at 9242035 block validation for a fee of $0.0005232. All the transactions were calculated with a 1 Gwei reward and set to 4000000 Wei.

Furthermore, utilizing the Remix IDE on Ethereum, some solidity operations were constructed and were simulated as smart contract operations on the platform. Over epochs 1 to 5, the transaction runtime was tracked and examined. The duration during which the platform validated the transactions was monitored. The experiment on Etherscan revealed that the average number of blocks needed to confirm transactions was 8502322. The simulation demonstrated that the blockchain offers a less expensive and more effective option for safe-

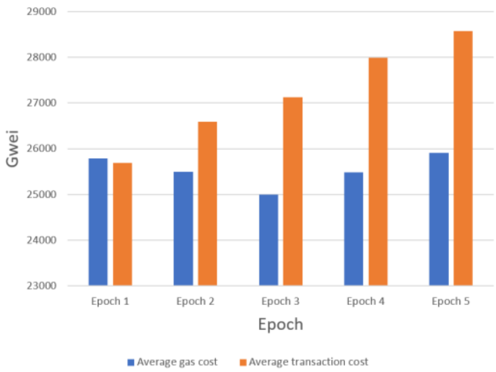

FIGURE 7. Average cost per epoch.

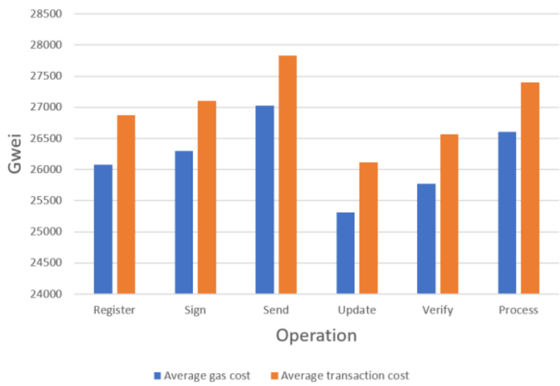

FIGURE 8. Average cost per operation.

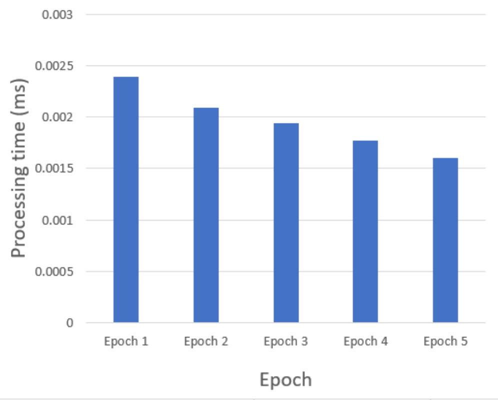

FIGURE 9. Average transaction time per epoch.

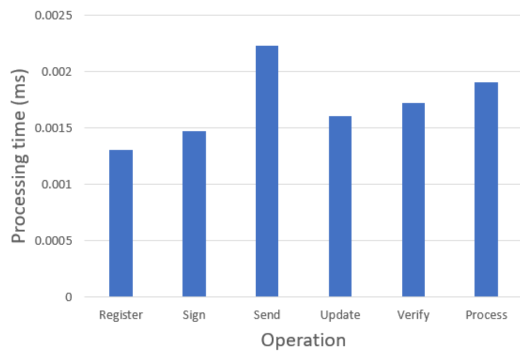

FIGURE 10. Average transaction time per operation.

guarding the data pertaining to loan request transactions and an efficient method of facilitating transactions between loan requesters and investors. The outcome depicts the cost-effectiveness of smart contract operations while automatically securing loan request data without an intermediary. The activities of all the registered entities on the platform are recorded on the blockchain network.

Read and write operations were set up as input and output of smart contracts and were configured for loan processing, data retrieval, and data verification. Regarding the simulation, the average transaction cost rises as throughput increases because nodes demand additional fees to process loan requests within the normal 15-seconds to 15-minute processing period. This is illustrated in Figure 7, accounting for the processing time of loan requests over the conducted simulations.

The results indicate that changing the transaction cost for a task does not negatively impact the times for reading and writing on the platform represented in Figure 8.

The time required to process and transmit loan requests maintains high transaction costs while reducing processing time. This is due to the fact that several smart contracts are executed during the transmission, updating, verification, and processing of loan requests as opposed to registration and signing events, as seen in Figures 9 and 10. So, optimization operations will have to be done on these processes to reduce latency and increase throughput on the platform.

An event overhead is a transaction a node broadcasts to establish a successful loan request. The evaluation parameters are calculated based on the number of nodes. The mean time to process requests to blocks is the average time a node spends receiving and transmitting transactions to and from the platform entities. This time is essential for determining how long it takes network nodes to broadcast a single stream of events to the network. This experiment helps us determine how to improve system methods by determining which operations cause high overhead costs.

The average cost of operations associated with establishing the blockchain-based crowdsourcing platform, like the registration of system entities and contract verifications, were less than 252,111 Wei. Regardless of the quantity of relevant information, there were minor differences in cost. In order to prevent send() request attacks, Ethereum's stack depth restriction limits parameter input to less than eleven.

As a result, a framework was designed to send the appropriate quantity of data over the system while looping loan request operations for several students. Miners publish the root of a Merkle tree for the transaction of blocks to the blockchain network to ensure the verifiability of transactions. This is accomplished since the transaction state is stored locally using a Merkle tree. Regarding validating the modified data, which demands cryptographic evidence, a mean transaction cost of 25356 Wei demonstrates that data can be encrypted and validated without extra gas consumption. This enhances the time for the processing of transactions because transactions are differentiated upon validation and broadcast to nodes on the platform.

VI. CONCLUSION

After graduating from high school, exceptional students should not be denied the opportunity to pursue postsecondary education due to a lack of financial assistance from their relatives. This work presents a blockchain-based crowdsourcing loan platform to provide financial assistance to students in tertiary institutions to fund their tertiary education. The blockchain employed in our work enables us to monitor the students and the investors, knowing that the information is correct as it is part of the chain, which has been verified due to the distributed system. This platform would provide chances for poor students by outsourcing funding for tertiary education that they would not otherwise be able to afford. We next intend to extend our idea by expanding the platform's functionality to include teaching and non-teaching staff.

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KWAME OMONO ASAMOAH received the B.Sc. degree in computer science from the Kwame Nkrumah University of Science and Technology, Ghana, in 2014, and the master's and Ph.D. degrees in computer science and technology from the University of Electronic Science and Technology of China, in 2018 and 2022, respectively. He is currently a Postdoctoral Fellow with Zhejiang Normal University. His current research interests include blockchain technology, big data security, and educational technology.

ADJEI PETER DARKO received the Ph.D. degree in management science and engineering from the University of Electronic Science and Technology of China (UESTC), Chengdu, China, in 2022. He is currently a Research Fellow with the School of Psychology, Zhejiang Normal University, Jinhua, China. He has published many articles in different international journals. His research interests include multi-criteria decision-making, information management, consumer behavior, and business intelligence and analytics. He has received many distinguished awards, such as the 2020 Chinese Government Scholarship for outstanding international students.

COLLINS OPOKU ANTWI is currently an Associate Professor with the Centre for Tourism Studies, College of Geography and Environmental Science, Zhejiang Normal University (ZJNU), Jinhua, China. His broad research interests include innovative technologies, entrepreneurs' and employees' well-being, and service and relationship marketing, particularly in-service industries.

SETH LARWEH KODJIKU received the B.Sc. degree in computer science from the University of Cape Coast, Ghana, in 2014, and the M.Sc. degree in software engineering from the University of Electronic Science and Technology of China, China, in 2018. He is currently pursuing the Ph.D. degree with the Computer Science and Information Engineering Department, Zhejiang Gongshang University. His current research interests include crowdsourcing, deep learning, and blockchain technology.

ESTHER STACY E. B. AGGREY received the B.Sc. degree in computer science from the University of Cape Coast, Ghana, in 2014, and the M.Sc. degree in software engineering from the University of Electronic Science and Technology of China, China, in 2019, where she is currently pursuing the Ph.D. degree. Her current research interest includes the exploration of deep-learning techniques in medical imaging.

QING WANG received the B.E. degree from Zhejiang Wanli University, China, in 2021. Currently, he is a graduate student at the College of Mathematics and Computer Science, Zhejiang Normal University. His research interests include data mining and artificial intelligence.

JIA ZHU received the Ph.D. degree from the University of Queensland, Australia. He is currently a Distinguished Professor with the School of Teacher Education, Zhejiang Normal University and the Deputy Director of the Key Laboratory of Intelligent Education Technology and Application of Zhejiang Province. His research interests include intelligent education, theoretical algorithms for database and data mining, federated learning, and blockchain with AI.