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RESEARCH ON THE DEVELOPMENT OF ENVIRONMENTAL ACCOUNTING AND ENTERPRISE INTERNAL MANAGEMENT MECHANISMS UNDER THE CONCEPT OF SUSTAINABLE DEVELOPMENT USING BLOCKCHAIN

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Abstract

The rapid increase in the number of industrial enterprises in recent years is associated with the number of environmental problems that threaten nature and humans around the world. Hence, information related to environmental effects and their subsequent cost must be documented by enterprises for planning and controlling corporate activities and related environmental issues. Companies' environmental effects and costs were never discretely classified or measured in standard accounting information systems. Because of their social responsibilities to society, businesses are compelled to account for environmental costs alongside production costs as part of their accounting practices. Environmental accounting (EA) helps industrial enterprises achieve environmental efficiency and economic efficiency. Regular accounting modules that are usually organized in a centralized architecture required trusted third parties for information management and are associated with security and privacy issues. Recently, blockchain technology is changing the concept of traditional enterprise accounting and management. The main aim of this work is to develop an environmental accounting information management system using blockchain technology for the sustainable development of enterprises. But the traditional consensus algorithms in blockchain are computationally inefficient. Hence, in this paper, we proposed a novel consensus algorithm named proof of accounting trust to select the trusted miner and validate the block for trusted storage of environmental accounting data. The proposed method is proved to be an efficient and secured environmental accounting and management system for assisting stakeholders of enterprise in decision-making.

Keywords: Environmental Accounting, Information Management System, Blockchain, Proof of Accounting Trust.

1. INTRODUCTION

As the number of industrial companies has grown, there has been a growing demand for the idea of sustainable development to be introduced. To ensure that future generations will have a better quality of life, environmental and resource conservation have become

worldwide requirements. This stressed the need for modern businesses to rethink their operational strategies. As a part of a sustainable development approach, it is important to consider both economic and social objectives. To be long-term, a company's business strategy must include values- and socially responsible management concepts (Bombiak and Marciniuk-Kluska 2018). With eco-efficiency principles, businesses will not only be able to profit from the goods and services they produce, but also by reducing waste and pollution in their production processes.

To achieve the triple bottom line of economic growth, environmental protection, and social equity, the government is urging businesses to adopt sustainable business practices. This necessitated the development of tools that would enable them to evaluate how their company is affected by environmental issues and how it affects the environment in which it functions. This need sparked the creation of environmental accounting (EA), often known as green accounting, a financial management tool designed for companies committed to long-term global sustainability, particularly those that are environmentally conscious. After the World Bank recommended that EA be included in the national income statistics, the EA element entered an important phase. EA promotes a holistic approach to economics and the environment, allowing for win-win outcomes that go beyond the scope of conventional environmental management (Tiwari and Khan 2020). Figure 1 depicts the overall cost accounting scheme that includes both conventional and EA information. Before the advent of EA, many industrial enterprises focused only on production costs, which resulted in unrealized gains and inaccurate financial statements. Companies may save money by discovering and assessing hidden costs associated with waste management and other environmental concerns when they do EA. An appropriate EA information management system is important for stakeholders for efficient decision-making.

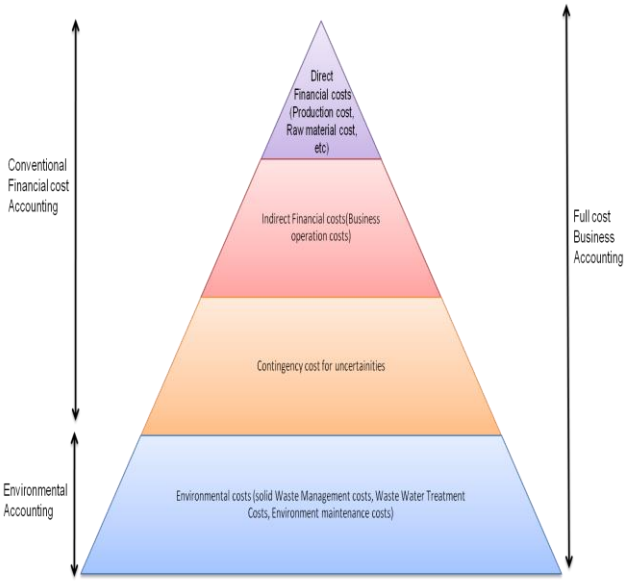

Figure 1: *Overall Cost Accounting Scheme*

Traditional centralized systems are less transparent and reliable. Blockchain technology (BT) is revolutionizing different sectors creating new challenges and opportunities. It is widely used in financial reporting and accounting because it limits the danger of fraud and the possibility of human mistakes, promotes an efficient information management system, and increases transparency and reliability. It is a distributed ledger database and decentralized platform. There is a consensus process in BT to ensure that the transactions contained in the new block are valid. Some of the common consensus mechanisms in BT are Proof-of-Stake (PoS) and Proof-of-Work (PoW). These traditional protocols are inefficient and less reliable (Saad et al. 2021).

EA information management system using BT is less investigated. This motivated us to develop an EA information management system using BT for sharing environmental information with stakeholders of the enterprise. In this research, we proposed a novel proof of accounting trust protocol for the validation of EA information. The additional part of this research is structured as follows. The associated literature and the problem statement are granted in Section II. The explanations of the presented work are provided in Section III. Section IV has results and discussions. The proposed paper's conclusion is presented in section V.

II. LITERATURE SURVEY

Based on real data, Pan et al. 2020 investigated the link between BT and corporate operating abilities. Using Blockchain-based life cycle assessment, Zhang et al. 2020 established a methodology for assessing how a product or service influences the environment. Using cloud computing for company accounting and information system development, Li 2019 was able to increase efficiency and speed up the process. Proof of Block and Trade (PoBT) consensus mechanism for IoT blockchain was suggested by Biswas et al. 2019. The standard accounting information recording method was suggested to be replaced with a BT called Smart Ledger by Zhang et al. 2019. Smart ledgers are automated algorithms that use BT to fulfill accounting ledger operations, such as keeping track of transactions. Fractional accounting transactions (FAT) and hierarchical accounting transaction execution (HATE) are the two methods that underpin their validity in the blockchain framework.

When it comes to the sharing of Digital Twin data in industries, Putz et al. 2021 presented an owner-centric decentralized sharing method. EtherTwin, their prototypical solution, demonstrated how to solve the various technical issues involved with truly decentralized data sharing, allowing management of linked information to be accomplished. Nanayakkara et al., 2021 developed a technique for selecting the best blockchain platform for tackling certain industry or business problems for which BT may offer a viable solution. Inghirami 2020 looked at the effects of BT on accounting and the systems that support it.

The blockchain-based system architecture was presented in the grain supply chain by Zhang et al. 2020, and a multimode storage methodology was devised that incorporates chain storage. Data tampering was made simple using this system's prototype, which was developed to address these difficulties and others. Food Trading System with COnsortium BlockchaiN (FTSCON) has been suggested by Mao et al. 2019 to enhance trust and security concerns in transactions. Authentication and permissions are enforced by the usage of consortium blockchain technology. According to Yang et al. 2020, a privacy-protecting blockchain-based access control architecture named AuthPrivacyChain has been suggested for use in business operations. The accounting information system designed by McCallig et al. 2019 is intended to improve the accuracy of financial reporting information. Using a blockchain, they employed accounting recordkeeping procedures to strike a balance between openness and privacy.

Security management of the accounting information model was studied by Shao et al. 2021. The fusion of feature information and autocorrelation feature matching was used to reorganize and manage information security. A Blockchain-Internet of Things (BC-IoT) transaction model was presented by Wu et al. 2019 for two applications in the accounting area. If certain assumptions are met, the BC-IoT transaction model may automatically collect, upload, and record all relevant transaction data.

Problem Statement

It's a well-known truth that traditional accounting does not include the environmental costs associated with production and indirect services, leading to misleading data that may be used to make inaccurate judgments. When environmental costs are integrated into the accounting information system, it assists the stakeholders of industrial enterprises in the decision-making process regarding the implementation of cost-efficient and eco-efficient production techniques. The blockchain-based information management system is a potential platform for the storage and maintenance of EA information. It has been shown that the Consensus mechanism is an effective validation technique in the blockchain and is an essential part of the chain's operation. Existing consensus algorithms are inefficient due to the usage of high computational power and low throughput.

III. PROPOSED WORK

The main aim of this work is to develop an EA information management system using BT to ensure efficient and safe storage of EA data. Initially, data is collected and preprocessed using normalization. Then the data is verified using smart contracts. Further, the data is validated using the PoAT protocol before storage in the new block. Figure 2 depicts the flow of the proposed work.

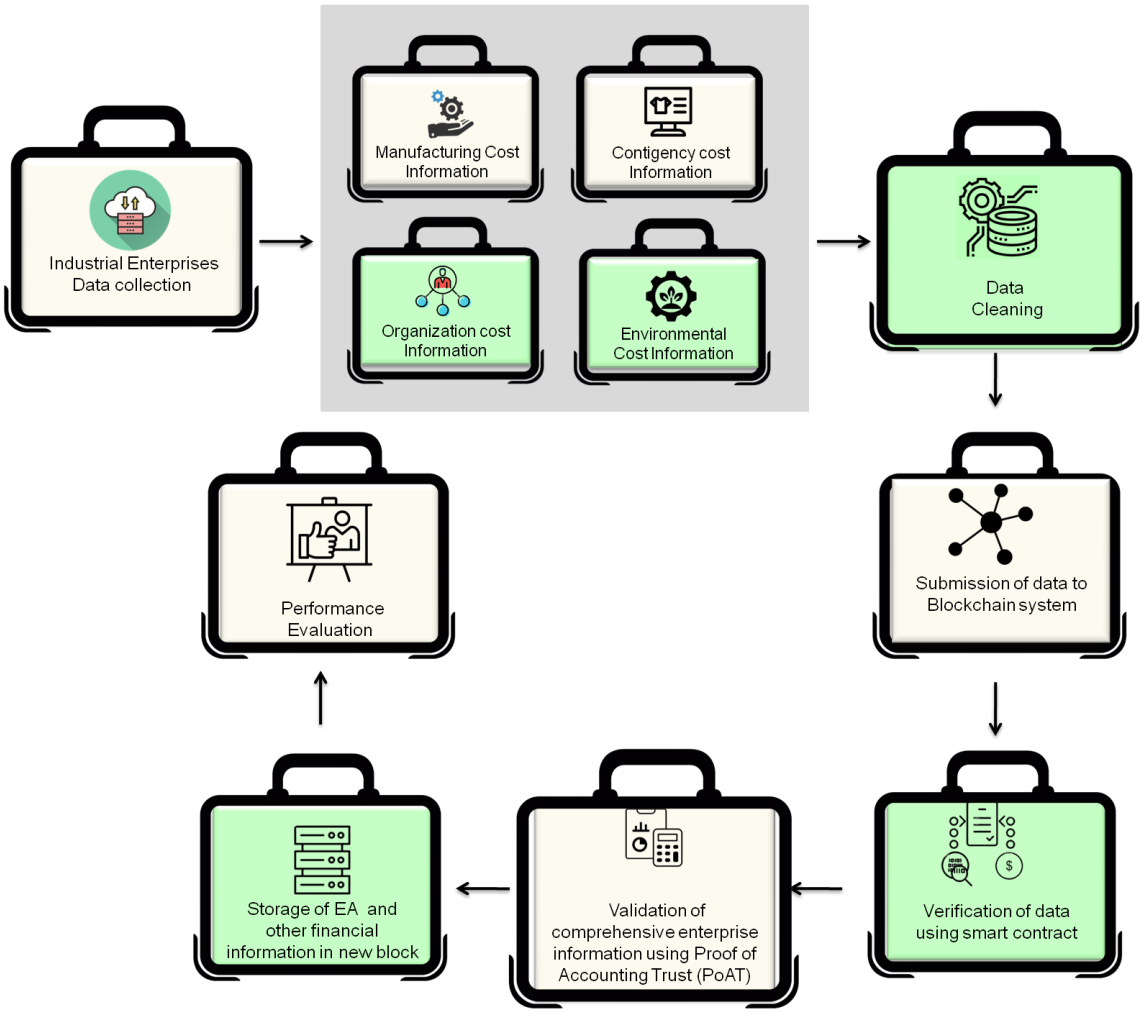

Figure 2: *Flow of the proposed work*

a) Industrial Enterprise Data Collection

This study selected Shenzhen Energy Company, one of the main power generation companies in China. It's linked to a lot of pollution and emissions. All of the company's annual reporting containing EA information, as well as social responsibility reports, investment prospectuses, and an independent environmental report note, are gathered from the firm (Liu and Liu 2020). This data also provides detailed insights into cost information related to production, organization maintenance, contingency, and environment maintenance.

b) Data Cleaning

Enterprise data that contains the financial and environmental information are preprocessed to improve the data quality in this stage. Finding and removing or correcting the dirty data is the primary goal of data cleaning. Data cleaning steps may have to be executed for eliminating duplicate information, non-essential contents, and irrelevant data, filling the missing data, and fixing the data inconsistencies. Then the data is embedded into data storage space. Data transformation is applied to modify the available information into an understandable and usable format.

c) Verification of enterprise data using Smart Contracts

Preprocessed enterprise data that consists of environmental accounting information and other financial information are submitted to the blockchain system. Smart contracts (SC) are automatically executed on the submission of information by the node for verifying the data. It is always executed to ensure the correctness of execution. The SCs are self-executing programs in blockchain technology for digitally enforcing verification or negotiation of a contract. Therefore, they offer credibility to contracting parties, without involving third parties. High-

level programming languages are used to create SCs. Every node in the blockchain network has a copy of these scripts. Every time there is a submission of the transaction by nodes, a smart contract checks to see whether the transactions follow specified rules. An error message stating that "transactions cannot be performed" is projected when the transaction is not following the rules.

d) Proof of Accounting Trust Consensus Protocol

Some of the traditional consensus algorithms assume a specific leader node as block creator (miner) or randomly select the miner. Also, they possess computational challenges to select block creators. To address these issues, PoAT is applied in this study to select efficiently the miner based on the trust level. All nodes' trust levels are calculated depending on the initial trust level, community engagement, and the experience rating between nodes' trust levels. Only nodes having a trust level of at least 80% are considered for selection. The node with a high trust level is selected as a trusted miner for creating the block. Figure 3 depicts the steps involved in selecting the trusted miner for block creation.

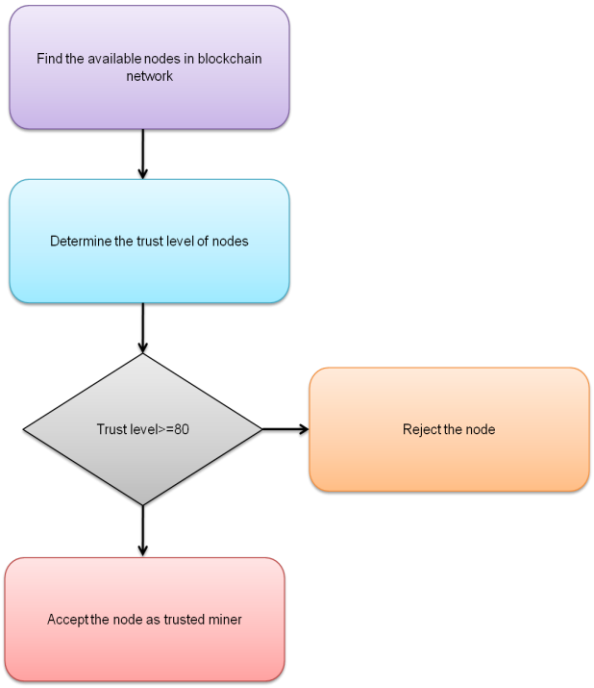

Figure 3: *Steps involved in trusted miner selection*

There will be a new block containing unverified EA information and other financial data created by the trustworthy miner. The trust level of the miner is assigned to the transaction stored in the block created by it. For each transaction, a trust level is calculated depending on the originator's trustworthiness and the hash values of the block. Secure Hash Algorithm calculates the block's hash value. It also contains only those transactions that have a high level of trust in them. As a result, the PoAT removes fraudulent transactions from the ledger and includes only legitimate ones. Once the block has been formed, it will be sent out to the rest of the network to be verified and confirmed by other nodes. Several other nodes will get the block and verify it by looking at its hash values and the trust level of the block's transactions and the block creator node. The validating node will vote in favor of the block and send it on to other nodes if it contains the correct information and meets the system's standards. If a trusted block maker creates the block, the block has the correct hashes, and the block transactions are likewise trusted, then the requirements are met. If the prerequisites are not met, the block will be rejected. In the same way, all of the validating nodes check the block. If the majority of the votes are in favor of the block, it becomes part of the blockchain. Now the block with environmental accounting information and other financial cost information is transparent to stakeholders of the industrial enterprise.

IV. RESULTS AND DISCUSSION

In this paper, an efficient environmental accounting information management system is developed using blockchain technology for the storage and maintenance of EA and other financial data of the enterprise. PoAT is applied in this work for the selection of the trusted miner and block validation. This section evaluates and compares the performance of the proposed PoAT method with existing techniques. The performance metrics used for validation of the proposed technique were average detection rate, block authentication time, block mining time, throughput, energy consumption, and the avalanche effect. The results were generated using MATLAB.

a) Latency

Latency on the blockchain refers to the lag time between when a transaction is sent and when the network confirms that it has accepted the block.

Figure 4 depicts the relationship between transaction latency and information submission rate or send rate. The send rate is measured in tps (transaction per second). As send rate increases, latency also increases. From figure 4, it is evident that the latency of the PoAT is less compared to the Optimized Blockchain Network (OBN). In addition, the relation between consensus latency and the number of nodes is illustrated in figure 5. Latency is shown to rise as the number of nodes increases. However, PoAT's consensus latency is lesser than that of SHBFT (Scalable hierarchical Byzantine Fault Tolerance).

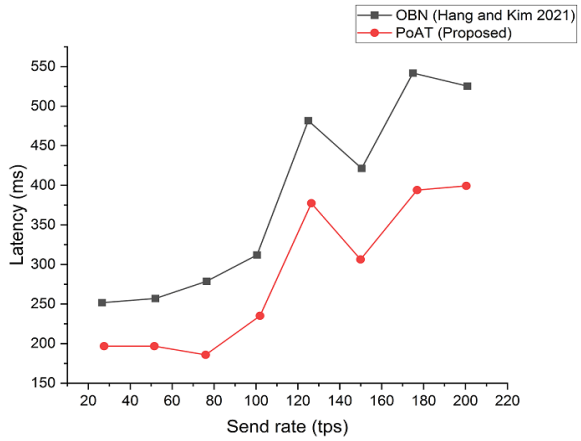

Figure 4: *Latency versus send rate*

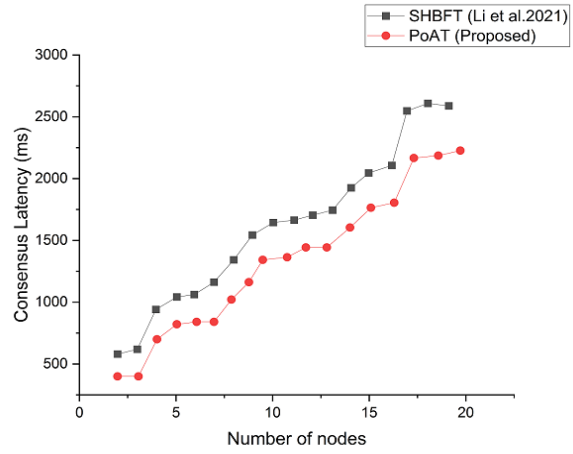

Figure 5: *Consensus latency versus the number of nodes*

b) Throughput

The transaction throughput is a critical performance metric. It measures the number of transactions occurring in the blockchain system at a particular time. From figure 6, it is evident that the throughput of the PoAT technique is greater than that of the existing approaches such as OBN.

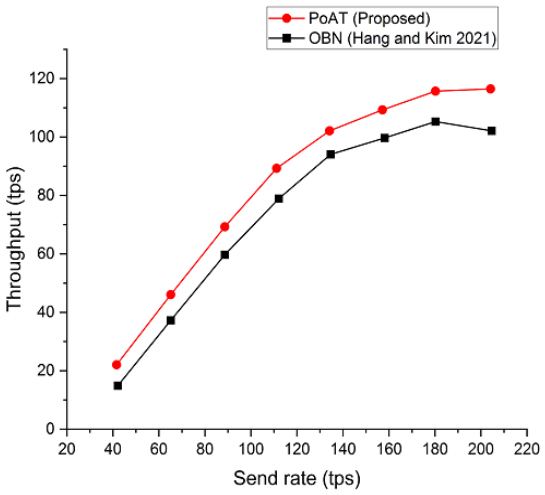

Figure 6: *Transaction throughput versus send rate*

c) Memory Requirement

Figure 7 depicts the memory required in MB (megabytes) against the increasing number of transactions during block formation. The memory required for storing the information is increasing with the number of transactions submitted to the system. It is observed that memory requirement is reduced in PoAT compared to that in PoBT (Proof of Block and Trade).

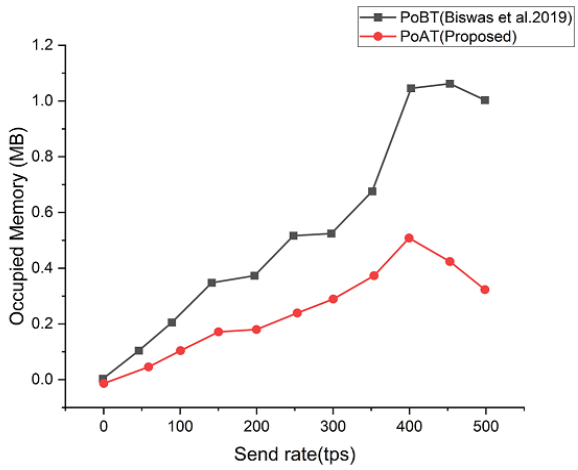

Figure 7: *Memory versus send rate*

Discussion

In this section, the EA information management system using blockchain is analyzed and compared with centralized systems in detail in terms of transparency, reliability, and security. The normal and steady functioning of the system

is what is meant by reliability. Typical centralized storage systems are simple to administer, but unstable, in organizations. In addition, since enterprise data is centralized, the associated data will be lost if a database is damaged. In this paper, EA data are stored in a distributed manner. Using a blockchain will guarantee that all nodes are synchronized and that each piece of information can be independently validated and processed. As a result, the suggested system has a high level of reliability. A blockchain-based system prevents tampering with EA information since each block includes the hash of the preceding block, making it open and unalterable. Consequently, BT ensures that the data in the system cannot be altered. It is impossible to aggregate and evaluate all of the data at once using a centralized system. Quality and uniformity of data are maintained throughout the collection process using BT. PoAT performance is also covered in this section Analysis of the results shows that PoAT performs better in terms of time needed to save EA information in the blockchain system and throughput. The efficient selection of trusted miners using PoAT greatly reduced the computation time and computational challenges. Smart contracts and PoAT, in particular, make the transaction process more practical, which, in turn, may raise the degree of trust and collaboration among the stakeholders.

V. CONCLUSION

Environmental accounting (EA) helps industrial enterprises in achieving efficiency in terms of environmental maintenance and economic growth. But efficient EA information management system is less investigated. Hence, this research is focused on developing EA information management system using blockchain technology. PoAT consensus protocol is proposed for efficient miner selection and block validation. The performance of the proposed protocol was compared to the existing techniques based on the performance metrics namely latency, throughput, and memory requirement. From the result analysis, it is shown that the EA system with PoAT is superior to existing techniques in terms of performance metrics. Hence, the EA information management system using blockchain is transparent, reliable, and secured which helps stakeholders of the enterprise in making efficient plans regarding environmental issues.

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