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THE INTERCONNECTED ROLE OF ARTIFICIAL INTELLIGENCE, BLOCKCHAIN, AND THE INDUSTRIAL INTERNET OF THINGS IN THE DIGITIZATION OF SMALL AND MEDIUM-SIZED BUSINESSES

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ABSTRACT

Small and medium-sized businesses (SMEs) have significantly increased their efficiency and production during the past several years as a result of digitization. As more SME stakeholders connect, access, exchange, add, and modify transactional executions, the process of automating SME transaction execution is becoming more complex. Partnership exchanges, stable financial management, manufacturing and productivity, together with privacy and security, are all necessary for SMEs to have a healthy lifetime. Another significant challenge when creating and administering a secure distributed Peer-to-Peer industrial development environment for SMEs is the interoperability platform issue. Due to the existing nature of centralised server-based infrastructure, it is difficult to manage the operations of SMEs' integrity, transparency, dependability, provenance, availability, and trustworthiness across two different firms. Using collaborative techniques of blockchain, the internet of things (IoT), and artificial intelligence (AI) with machine learning, this article addresses these issues and presents an innovative and safe framework with a standardised process hierarchy/lifecycle for dispersed SMEs (ML). The "B-SMEs" blockchain, which offers answers to cross-chain platforms, is created with an IoT-enabled permissionless network topology. B-SMEs also address the issues with lightweight stakeholder authentication in this. Three different chain codes are used for that purpose. Before being stored on the blockchain's immutable storage, it manages participant SMEs' registration, day-to-day information management and exchange across nodes, and analysis of partnership exchange-related transaction details. The goal is to manage and optimise the daily volume of SME transactions while using AI-enabled ML-based artificial neural networks, so that the suggested B-SMEs use less processing power, network bandwidth, and preservation-related concerns throughout the whole process of SMEs service delivery. The simulation results demonstrate the benefits of B-SMEs, enhance the rate of ledger management and optimisation while sharing data between various chains, up to a maximum of 17.3%, and decrease the system's computing resource consumption to a minimum of 9.13%.

As a result, as compared to how SMEs now operate, just 14.11 percent and 7.9 percent of B-SME transactions require network bandwidth and storage, respectively.

INTRODUCTION

The nature of SME development and connection has altered as a result of the current state of global business and companies. Small and medium-sized enterprises are only acting as receiving and adopting

regulatory bodies due to the competitive fluctuations in the market and the daily issues that have emerged in more recent times. The majority of the ratio to economic development1 is contributed by the manufacturing sectors. Whereas small and medium-sized businesses, particularly those in production and manufacturing, are a priority for developing nations across the world. While planning and building units, one must take into account the size, scalability, and financial limitations of production and manufacturing development. Aside from that, entrepreneurs are able to make their ideas work because of the volume, geographic reach, skill and capability of their workforce, and the intensity of their work. These are the fundamental elements of SMEs that support economic growth2. The most current study on US economic cooperation and development (2021) claims that more than 90% of all businesses are market fluctuations, which includes small businesses nationwide and SMEs3. Nonetheless, SMEs account for 50% of all employment in the nation and provide more than 47% of the growth in the company gross domestic product5. In a setting where the focus is on the client, the production and manufacturing facilities are set up with the procedures needed to respond to mass customisation utilising the internet of things (IoT)

The possibility to sustain SMEs in a better way than conventional ones and adapt them to allow for greater flexibility and agility is provided by the new paradigm of digitalization. As a result, SMEs' engines maintain client expectations by offering increased responsiveness in line with those criteria. Yet, quality is a crucial element of customer-oriented infrastructure, and by placing too much emphasis on it in the transition process, digitization process. The following categories represent the process hierarchy for developing SMEs: Designing, planning, producing, and providing services are among the first four.

While the primary goal of measuring the positive impact of production and manufacturing initially is the quality of the product that is shipped out to the clients of SMEs. The designers of manufacturing units for SMEs that have changed over time and are now converted to production must wait until there are suggested standard quality methods and a sufficient hierarchy. As a result, these modifications to the structure of the process with developers preserve bulk customisation. Decisions based on information gathered in real time from the customer and market sides have become easier thanks to quality measurement. To design, plan, manufacture, develop, and perform functions within the defined resource constraints, such as less time and limited cost while fulfilling the customer requirement, it is crucial to prioritise the processes that support SMEs' production and manufacturing and mitigate product development-related risks. 6 \s. So, it is important to consider how digital manufacturing affects quality assessment and to make sure that node transaction events are concurrently functionally coupled and synchronized.

In contrast, the Internet of Things (IoT) and wireless sensor networks (WSN) have enabled SMEs to transform their manufacturing processes and the way that data is traditionally collected, examined, analysed, preserved, and presented among linked units7. Utilizing the most recent version of smaller batch sizes allows for quick and efficient response to customer-generated records. Industrial IoT aims to effectively collaborate with SMEs' manufacturing processes, which are often easy to distinguish from large-scale production. Due to industrial environments, where items are independently produced using a customer-specific methodology. In order to create a cost-effective approach, which implies the cost is similar, mass customisation, a notion that has significantly advanced in industrial production, is

required. It primarily focuses on centralised server-based decision-making procedures, with a highly constrained scope for value-added evaluations of particular products. However, SMEs and industrial IoT-enabled framework collaborate to replace them with flexible, reconfigurable manufacturing and decentralised systems that offer effectiveness, responsiveness, strategic management, and the development of decision-making capability, as shown in Fig. 1 (using the example of a manufacturing company). (Use Draw.io to create images.)

Additionally, the development of digital technology, like IoT technology with SMEs, improves productivity and income, captures market shares, builds brand awareness, allows for mass customization, provides real-time feedback that improves organisational implementation and necessary changes, aids in decision-making, and assesses customer sentiment9. On the other hand, these highlighted problems significantly impede the digitization and transformation of SMEs. Due to the initial high engineering and investment costs and the unsatisfactory and ineffective results, many businesses are hesitant to and dissatisfied with speed, cost, time, and related resource restrictions. Nevertheless, a number of artificial intelligence (AI)-enabled machine learning (ML) approaches (supervised, unsupervised, and semi-supervised) are proposed9 to manage and improve manufacturing and production-related data or transactions of SMEs in a ledger. By fine-tuning the aforesaid SMEs' operations and integrated market fluctuations, it is possible to significantly broaden the scope and context of AI development. Most significantly, by utilising post and share methods to raise awareness about new manufacturing, production, and industrial development, the combination of AI with social computing plays a vital role in the creation of powerful digital marketing strategies for SMEs. Performance and productivity, however, are somewhat dependent. As a result, it qualifies as a long-term benefit.

In the existing situation, SMEs transactions are acquired and delivered through a centralised server-based network architecture. Because of the lax security, it immediately affects the ledger integrity and privacy of SMEs.

This indicates that information is easily accessed and traced, particularly when monitoring consumers' personal details online. To prevent tampering and forgery, distributed ledger technology has been widely utilised in a range of small- and medium-sized enterprise contexts. 10–13. But, blockchain has lately made it possible for SMEs to safeguard their operational systems and process hierarchies in order to achieve ledger integrity, transparency, traceability, and trustworthiness through distributed applications (DApp). The already-existing SMEs are integrated with the cooperative AI-blockchain approach, which helps to secure the process hierarchy, maintain the customer-orientation strategy, encrypt information exchange between customers and ecosystem, protect distributed node-to-node transactions, and platform interoperability. Moreover, the individual node transaction event is saved before being properly verified and validated using chain codes (smart contracts). The involved stakeholders are connected by a chain-like structure and chronological sequence in a public permissionless network to start small exchanges and transactions. This aids SMEs in achieving privacy and security by preserving optimal documents in a secure storage container with hash-encrypted form that are difficult to alter or falsify.

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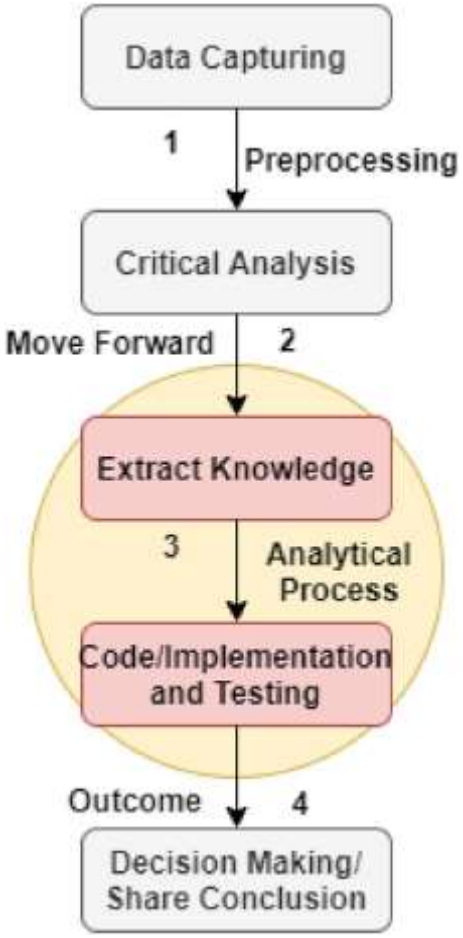

Figure 1 The current process of SMEs with IoT for data management and decision

The following are the primary scientific contributions and goals of this paper:

- This article discusses the processes that exist today between customers and SMEs, including interconnected manufacturing, production, and industrial units, as well as data collection, management, and optimization. A new paradigm is created by the application of digital technology and AI, according to analysis. Analysis of how SMEs affect a country's economy is likely to show the advantages of adoption.
- We discuss comparative study findings on digitalization, SMEs, industrial IoT, AI, blockchain, and their transformation that have been done throughout Asia over the past several years in this article.
- The conclusion of the study, from which a standard process hierarchy was established, allowed for the standard, safe, and secure management of client interactions with SMEs. The suggested B-SMEs (a blockchain- and AI-enabled distributed framework) offer a platform where the DApp is conceived, developed, and deployed in order to promote a transparent transactional environment. The primary goals are to manage automation connected to SMEs, particularly transaction verification and validation, exhaling, and resource sharing among participants.

- A lightweight authentication strategy that lowers the cost of computing resources as well as network bandwidth and storage is made possible by the development of distributed public permissionless networks that are integrated with AI.
- For the registration of stakeholders, SME transactions and exchange updates, and information management and immutable storage optimization, three distinct chaincodes have been developed and applied. Nevertheless, specific transactions are secured by using the NuCypher threshold, which is re-encrypted during delivery. In order to plan, start, manage, and authorise transactions as well as the related information exchange among involved stakeholders, the proof-of-work (PoW) and proof-of-stack (PoS) predefined Ethereum consensus is implemented.
- The implementation and deployment of DApp BSMEs in real-time include a number of open problems, restrictions, and concerns that will be taken into consideration as future advances for technical maturity. This study outlines a few of these issues.

The remaining portion of this essay is organized as follows: Several IoT, blockchain, and AI-enabled strategies used in an industrial setting as well as SMEs for improved production and manufacturing are covered in Section "Related Work." In Section "Basic knowledge and preliminaries," the primary understanding of blockchain, IoT, and AI-enabling technologies is offered together with the issue formulations and problem descriptions. In the section under "Proposed framework," the B-SME distributed framework with blockchain, IoT, and AI capabilities is suggested for the establishment of smart SMEs and associated procedures. On the other hand, the "Future Direction" section emphasises potential research directions and discusses open implementation concerns, obstacles, and constraints. Lastly, in Section "Conclusion," we wrap up our essay.

Related work

In the context of digitalization, the idea of "digital transformation" is seen as an efficient and effective business strategy utilized to develop better company business practises than the ones already in use14. By offering business strategies, it lessens the effect of external constraints and brings about a significant shift in SMEs' operations. As a result of the use of digital technology (DT), a number of difficult problems are emerging that affect both the social values of businesses and the sustainable growth of the economy. Nonetheless, effective DT use enhances the economic and social circumstances in the area. Focusing on the many stages of manufacturing growth, production, and sustainability is necessary to empower businesses at every level. Owing to this, several studies have been published that looked into the different problems, difficulties, and restrictions and recommended various solutions, such as regulating the influence of This allowed us to distinguish between similar approaches, models, procedures, tactics, and conceptual architectures that leverage blockchain-based modular framework, industrial IoT, and AI to improve the capabilities of SMEs. a few connected

The following publications, which are included in Table 1, emphasise the research gaps regarding the SMEs' present systems and additional discussion of open modifications.

Research papers	Research development	Research benefits and outcomes	Research challenges, limitations, and issues
A role of moderating an entrepreneurial orientation to design a sustainable SMEs[14]	This study proposed practical and theoretical implications related to managers and ledgers of SMEs. The offered mechanism helps to transform their existing companies into digital enterprises. For this purpose, the study presented various theoretical implications, processes, and strategies that help in digital transformation	Volatile high velocity of business environment Dynamic capability review Resource-based review Benefits for startup SMEs as well	Cross sectional limitations External validity issues Hardly handle the generation to a large population Defect of context insensitivity The result of the proposed model in up to 68%
Automobile assembly model for design and implementation of SMEs using federated AI and blockchain technology[15]	The paper presented a new design for SMEs called Trust Threshold Limit (TTL) that helps moderate the existing use of embedded tools, sensors, energy, and cost of functions in the production and manufacturing process	Smart contract is involved in the automation of operational controls, events of nodes executions, and legalization of production and manufacturing Blockchain-based automobile assembly model	Trust threshold limit Limitation in federated learning of AI Consume more computational power to evaluate transactions Customization and graphical UI
An empirical study of SMEs: Analysis of the relationship between digital transformation and performance[16]	The authors of this paper presented an empirical analysis of the current performance of SMEs undergoing digital transformation and demonstrated a state-of-the-art review description	Interview method used The process of sustainable development is proposed Analysis digital transformation on financial performance	Cross chaining platform limitation Automation and deliverance related challenges Centralized data management and organization issues
A collaborative approach of knowledge, diffusion, and blockchain technology in SMEs[17]	This research presented a novel process hierarchy by adopting knowledge management perception, drawing on the distributed ledger technology, and highlighting the involvement of diffusion in intelligent SMEs and related transactions	A questionnaire-based evaluation Perform a logistic regression to analysis the determinate of futuristic digital transformation Use blockchain permissionless public network	Cost of data privacy and security Scope of data automation Interoperability platform issues Expensive data preservation on distributed storage
Fintech for SMEs sustainable business model and transformation[18]	This research highlighted the role of fintech in sector development under the influence of the fourth industrial revolution. In addition, this paper presented a novel framework using the ReSOLVE model for both the theoretical and practice advancement in SMEs	Sustainable business model Improve circular economy practices A conceptual framework is proposed Use Fintech-enabled ReSOLVE model	Linking fintech application Privacy and security issues SMEs data management and optimization limitations

The green blockchain for SMEs[19]	This paper proposed a secure distributed monitoring framework for the execution of core operations of SMEs using a blockchain public permissionless network	Eco-friendly systems Involvement of IoT technology Circular economy development Perform computationally intensive ML task	Regulatory and compliance issues Risk controlling procedure for data organization Data integrity and transparency-related challenges while connecting different SMEs

A contemporary collaborative approach is made possible by the continual integration of rapidly developing technologies, such as artificial intelligence (AI), machine learning (ML), federated learning, blockchain, hyperledger, IoT in industry, and green technology for SME assets. 20–28. Cryptocurrency, an automated distributed transaction platform that manages a variety of requests without any centralized or outside interference, is where the distributed ledger technology first gained prominence. In this way, SMEs and IoT used blockchain as a secure infrastructure or ledger to register changes to SMEs' professional status and occurrences of node transactions. Yet, there are several more benefits of collaborating with blockchain, IoT, and AI, including increased SMEs' productivity and competence, cost-effective transaction delivery, and safe information transmission. environment. In order to create a secure and protected SME environment, we therefore thoroughly reviewed a number of related studies that do so (as discussed in Table 2).

The following comparison list is provided:

- using an approach for artificial intelligence.
- Machine learning.
- Internet of things.
- Industrial and manufacturing process hierarchy
- Process development
- Customer oriented strategy
- Define relationship between customer and SMEs
- Information management and organization
- Blockchain involvement.
- Addresses privacy and security.

preliminary information and fundamentals

The problem's foundations and first steps are discussed in this part, along with some potential solutions, which are outlined below.

Notation, statement of the problem, and description.

This article examines three distinct and significant issues that are currently SMEs' top concern. These issues are SMEs' data creation and process hierarchy, data management and resource consumption, and maintenance of privacy protection. These difficulties have already been addressed separately with a variety of effective solutions, but one of the difficult problems is combining all these answers into one

setting. Nevertheless, there is currently no standardized method that can effectively and dependably combine various technologies into a unified platform.

As we stated, SMEs do not currently have a defined standard process hierarchy or lifespan. In this sense, the suggested effort recognized and addressed this issue. Hence, as illustrated in Fig. 2, we suggested a B-SMEs standardized process hierarchy/lifecycle. This lifespan adheres to the norm for IoT infrastructures in terms of data collection and management (as per US economic cooperation and development statute). In order to transfer data from one node to AI-enabled data resource management, wireless sensor networks (WSN) collaborate with IoT devices, as seen in Fig. 2. The following process hierarchy of IoT-enabled devices for manufacturing, production, and industrial SMEs is discussed:

- Data collection (capture-as-the-data-occur).
- Data examination.
- Data extraction.
- Data analysis
- Design procedure to schedule process (priority bases).
- Implement a pathway for data traveling with the use of WSN.

We assess a classification technique for data management and optimization that looks for redundancy in data/transactions of SMEs and extracts the original ones while tossing out duplicates during the pre-verification process. This approach enables control of computational resources to lower computing costs and transmit verified data to the ledger for additional processing. in the suggested B-SMEs to use this ML approach, particularly artificial neural network (ANN), to manage daily transactions. ANN views the analysis of the ledger as a breakthrough since it resolves the problems with data management, organization, and optimization. Prior to implementation, we identified some flaws that were beginning to appear in the distributed data management environment, such as problems with data/transaction detection and unreliable identification of files in various nodes. To evaluate these problems, however, we build a data identification system utilizing machine learning and link it to ANN, which effectively extracts patterns, detects, recognizes, and categorizes data flows/transactions of SMEs. In addition to connecting with the ANN to schedule logs for processing, a self-correlation also provides a large-dimensional space for classification, reducing the risk of data capture and loss.

	Research years and references									**Our proposed work**
Categories	**2013**[20]	**2014**[21]	**2015**[22]	**2016**[23]	**2017**[24]	**2018**[25]	**2019**[26]	**2020**[27]	**2021**[28]	**2022**
Artificial intelligence	✓	✓	✓	✓		✓			✓	✓
Machine learning	✓	✓	✓	✓		✓			✓	✓
Internet of things					✓		✓	✓	✓	✓
Industrial and manufacturing process hierarchy						✓	✓		✓	✓
Process development	✓	✓		✓			✓	✓		✓

Customer oriented strategy	✓		✓	✓	✓	✓			✓	✓
Define relationship between customer and SMEs		✓				✓	✓	✓		✓
Information management and organization	✓						✓	✓	✓	✓
Blockchain involvement						✓	✓	✓	✓	✓
Privacy and security		✓		✓		✓			✓	✓

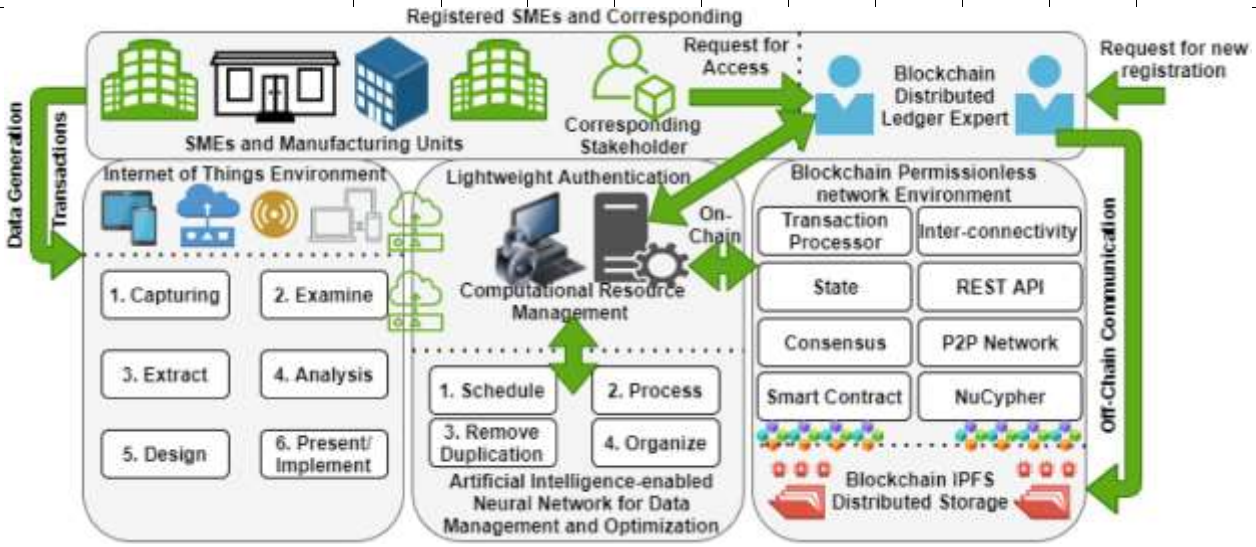

Figure 2. The proposed B-

Following is a discussion of the ANN's notation in relation to classification:

- Weight (w’).
- Bias (b’).
- Input neurons (n’).
- Counter (c’).
- Single layer inputs (s’)
- Treshold (t’).
- Output neurons (o’).
- Activation function (σ).

For the purpose of data verification, a weight is defined whose goal is to link the participating neurons in the ANN architectural design. A single neuron can only store so many events or node data or transactions (values of data occurring). Nevertheless, each constructed ANN neuron assigns a distinct value or label. Thus, the input values are n1', n2', n3', and ns', with the corresponding weights being w1', w2', w3', and ws'.

The following sum of inputs and weights illustrates the intensity of excitation:

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$$\text{excitationfluctuation} = \sum_{c'-1}^{s'} w'c' * n'c' \quad (1)$$

The output neuron (o')=to the total (excitation fluctuation), which is defined in the equation presented below, if the range of the threshold fluctuates in an increasing way of the suggested Approach.

$$\sigma = \begin{cases} 1 \text{if total of } n' \text{ and } w' \text{is grater than is equal to "} t' \text{"} \\ 0 \text{if total of } n' \text{ and } w' \text{ is less than is equal to "} t' \text{"} \end{cases} \quad (2)$$

The (sigma) function, on the other hand, is carried out as a nonlinear function, with t' value equal to '0' and t' down towards the minus side taking a negative sign.

Because of this, we alter the parameters of t' by supplying values for b' and w', such as w'0=negative t'. So, to maintain ANN large-dimensional for data classification, such as if n' value of n'=1 with formal inputs, a bias values b'0=t' is introduced.

The expression for the output (o') equation is as follows:

$$o' = \begin{cases} 1 \text{ if total of } n' \text{ and } w' \text{is grater than is equal to "} t' \text{"} \\ 0 \text{if total of } n' \text{ and } w' \text{ is less than is equal to "} t' \text{"} \end{cases} \quad (3)$$

proposed structure

The suggested B-SMEs' operational hierarchy is shown in Figure 2. a system that combines blockchain technology with AI and is separated into three folds. The IoT process hierarchy is first, and it's made to gather, segregate, look over, and evaluate SMEs' created data or transactions. After careful consideration, we develop a plan for data transmission across wireless sensor networks and put in place a management structure to oversee daily operations. Second, the AI compartment is divided into two parts, such as the AI-enabled neural network algorithm and computing resource management. To give an automatic capacity to provide access to each application request following verification through the DApp, a lightweight authentication is constructed in the middle. The Blockchain Distributed System handles the registration of new SMEs. Te BDLE permits stakeholders to start transactions in the chain and exchange information, and it is in charge of starting new registration validation after a thorough study of requests. It only has to be done once; after that, accessing the ledger merely requires providing registration credentials.

To manage and optimise data, an artificial neural network or other machine learning method powered by artificial intelligence is utilised. This process eliminates data/transaction duplication and arranges logs in a sequential sequence, which simultaneously decreases the demand on computing resources and the preservation workload.

Third, the blockchain permissionless public network is implemented alongside two distinct chains of communication, such as on-chain and off-chain (a peer-to-peer network with node interconnectivity).

These two specifically built channels of communication address a variety of chain transactions, including application requests, node-to-node interactions, operational control, external communication, and information sharing. For instance, internal transactional queries are sent to the on-chain and are implicitly processed. On the other hand, all explicit actions (off-chain/cross-chain platform) are addressed through off-chain communication. To plan a list of transactions, which is given by outsourcing computation and execution, is the primary goal of a blockchain transaction processor, as illustrated in Fig. 2. (Using Draw.io for image generation). As shown in Table 3, we combine the idea of NuCypher threshold re-encryption with smart contracts and consensus policies for transaction protection and automation. This is a brand-new paradigm that has been put out in a setting for public cryptographic encryption that doesn't offer cypher conversion. By doing this, it lowers the computational load by computing hashes of individual transactions that take place in B-SMEs. Whereas the records of individual transactions that take place in the B-SMEs chain are kept on an interplanetary file storage system (IPFS). The reason for using this distributed immutable storage is that it offers ledger preservation features at a lower cost than other distributed storage, like Filecoin. The main benefit of using it is that it allows for scaling and cost-effective hierarchy (calculates usage).

Code chains (smart contracts)

In this part, the article examines the three different chain codes' design, creation, and deployment goals. The following is a list of contracts and consensus policies the functions SMEsR(), corresponding(), addNInfo(), updateInfo(), logsPre(), PoW(), and PoS (). As indicated in Table 3, the operational structure of the proposed B-SMEs is divided into two distinct folds: chain codes and consensus policies with digital signatures. First and foremost, these contracts are intended with the intention of automating the verification and validation of new startup or SME registrations along with the relevant stakeholder. The involved parties and the system begin Te SMEsR() and associated() contracts (B-SMEs DApp). According to the policies established by the B-SMES consensus (proof-of-work and proof-of-stack), which are included in Table 3, these contracts are in charge of registering new SMEs. To keep track of every transaction made by all of the participating SMEs and exchange, the method addNInfo() was developed. Although every transaction is protected by NuCypher threshold re-encryption and stored in the blockchain's IPFS immutable storage across several nodes. With the aid of an ML-based neural network technique, it also optimises while deleting unnecessary records and maintains the ledger for B-SMEs. Nevertheless, the ledger updates after receipt of an update request from any relevant SME with regard to amended transactions; this is only achievable when 51% of the connected SMEs vote in agreement with the implemented protocol for B-SMEs' digital signatures.

RESULTS AND DISCUSSION

After discussing the data management and optimization utilizing ANN problem (as covered in Section "Notation, problem formulation, and description"), let's move on. The administration of ledger data for B-SMEs, optimization, computational processing with lightweight authentication, and privacy protection

are presented in this part along with the simulation results. As shown in Fig. 3, we link a blockchain permissionless P2P public network with additional computing nodes to power the data processing for light-weight B-SMEs authentication (using Draw.io for image generation). Each individual node has eight-core i9 Evo processors (3.0 GHz with turbo boost). The systems utilize the blockchain docker and Windows 11 while running the generic kernel on their backend.

- A fixed size of node transactions=4 MB.
- Local area network is designed with limited bandwidth of up to 1 Mb/s.
- Heterogenetic nodes interconnectivity is designed for intercommunication with two channels.

Input Constraints: The maintenance and structuring of SMEs ledgers is the responsibility of Blockchain Distributed Ledger Expert.

Experts can keep track of trade specifics and transaction timing.

Expert can respond to application requests from involved parties.

A professional can control distributed storage and updates.

Variables: Main (): X.file[x.txt]:

SMEs registration,

(SMEsR());

register stakeholder for individual SME,

(Corresponding ());

communication channels,

(comCh());

add new information/records,

(addNInfo());

information exchange,

(infoEx());

update information,

(updateInfo());

logs preservation,

(logsPre());

Blockchain timestamp [blockchain-ledger execution];

Process: if SMEs is! = SMEsR()

then,

if stakeholder is! = corresponding()

then

update SMEsR() and corresponding(); add new registration of SMEs and corresponding; each request checks and validates; individual SMEs transactions are records in addNInfo();

and updateInfo; counter (cont()) + 1 = true; exchange; any modification to earlier records made by updateInfo();

All contracts and data are handled and managed by Blockchain Distributed Ledger Expert

the logsPre();

In addition, the logsPre() keeps track of various activities like SME registration (SMEsR()), stakeholder registration for specific SME (corresponding()), communication channels (comCh()), information exchange (infoEx()), information update (updateInfo()), logs preservation (logsPre()), blockchain timestamp [execution], and others.

Else edit, maintain, add new, and exchange information; trackback;

Else check state, add new, manage, update, and exchange;

trackback;

Outputs (Results): SMEsR(), corresponding(), addNInfo(), updateInfo(), and logsPre().

Consensus Policies and Digital Signature: Proof-of-Work, PoW();

Proof-of-Stack, PoS();

Table 3. Chain codes implementation.

As seen in Figs. 2 and 3, we implemented BDLE smart contracts to monitor CPU utilization and set computational energy limits for stakeholders' lightweight authentication. The lightweight authentication 3D simulation results (Fig. 4(1),(2)) demonstrate that the present PoW and PoS use more resources than the B-SMEs.

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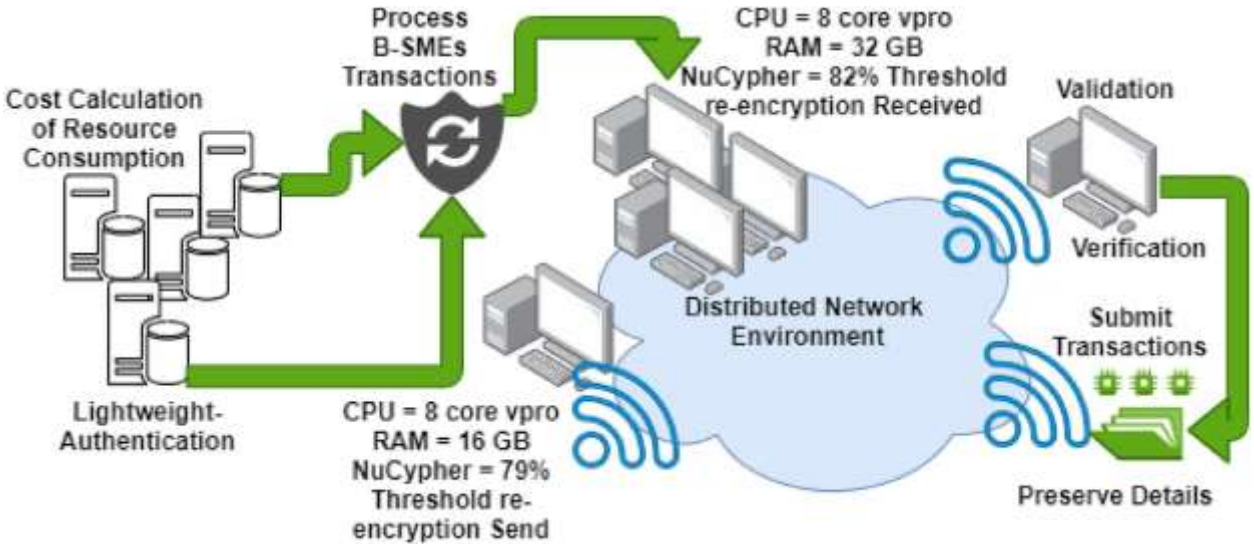

Figure 3. Te simulation results of the proposed B-SMEs consensus for lightweight authentication, (1) shows the fuctuation of previous predefned consensus (PoW), and (2) shows the diference of adoptation of B-SMEs consensus (PoW and PoS)

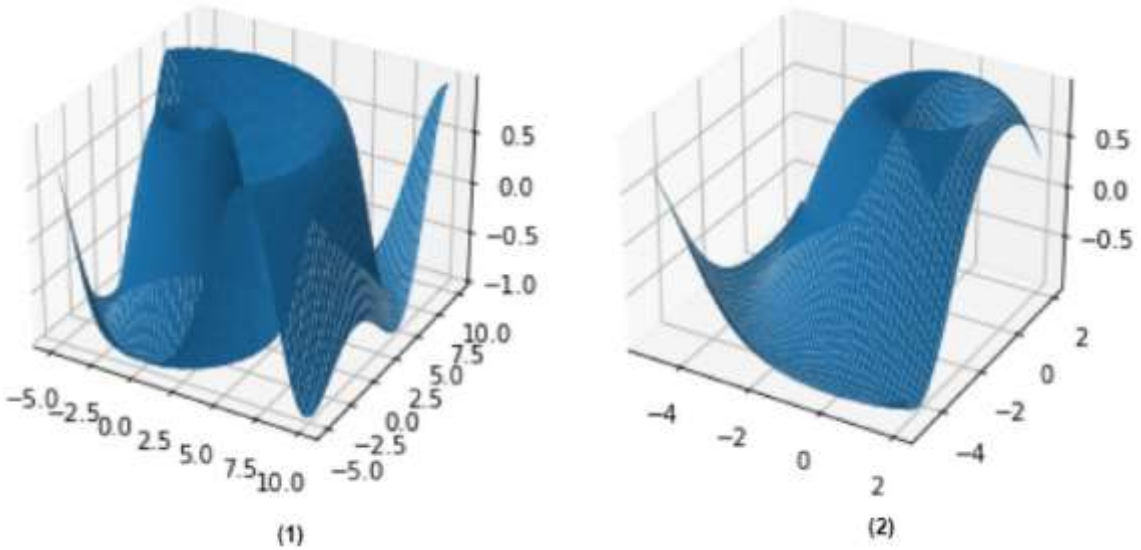

Figure 4. Lightweight authentication simulation assumptions.

The suggested B-SMEs tailored consensus reduced the workload to 9.13% and achieved impressive cost reduction, as seen by the comparison between the two Figures. Yet, by implementing the B-SMEs consensus in real-time, we are able to reduce the utilisation of resource limitations throughout the whole user authentication process and offer reliable performance.

In Fig. 5, an analytical assessment of the data/transaction collection and processing of SMEs using IoT is shown. The simulation's outcome is separated into four categories, as shown in Figs. 5(1) and (2), which show the frequency of data created by IoT devices and their metrics, including the number of data

captures or transmissions made via WSN and loss values (function). The difference between the data transmitted and the analysis, which are exactly proportional to one another, was shown in Figures 5(3) and (4) instead. This simulation works in conjunction with ANNs to maintain ledgers and optimize them. In fact, the integration of IoT with ANN boost's reaction times for data/transaction transmission while reducing latency and throughput. The actual results of the suggested B-SMEs showed that, in comparison to the present method of SMEs30-33, only 14.11 percent and 7.9 percent of B-SME transactions require network bandwidth and storage capacity, respectively.

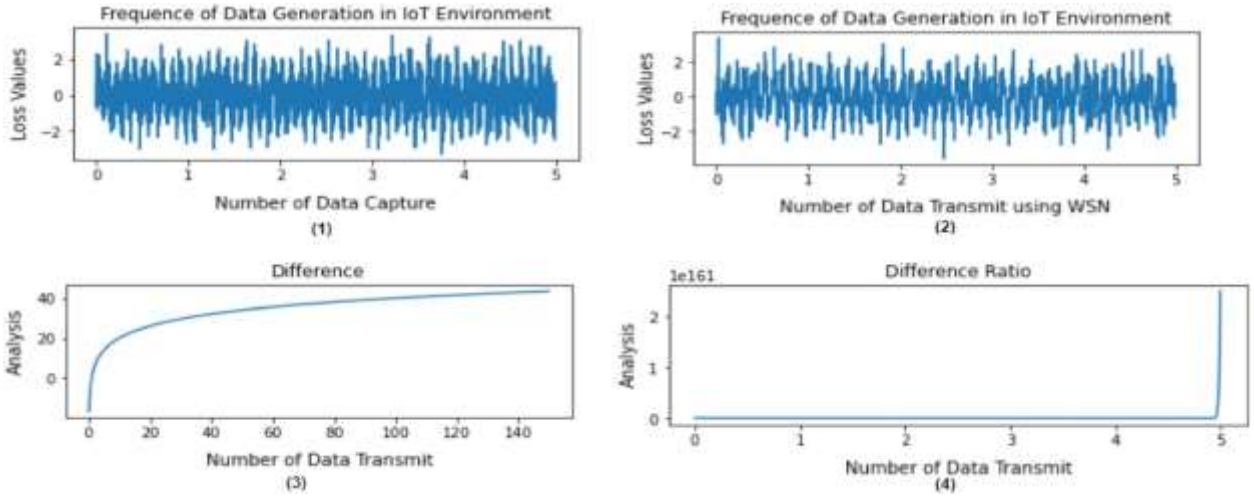

Figure 5. Frequency of data generation in IoT environment, (1) shows the number of data capturing, (2) shows the number of data transmitting, (3) shows the difference between the number of data transmission and analysis

(1), and (4) shows the difference between the number of data transmission and analysis (2).

The study includes a comparative table of a few relevant, well-known studies that leverage AI, IoT, and blockchain-enabling technologies to enhance the developments of small and medium-size firms' environment 29 in this context of comparison with other state-of-the-art. The comparison findings (in Table 4) demonstrate, however, that the B-SMEs functioned better and more effectively. As mentioned in Table 4, the evaluation's specifics are as follows:

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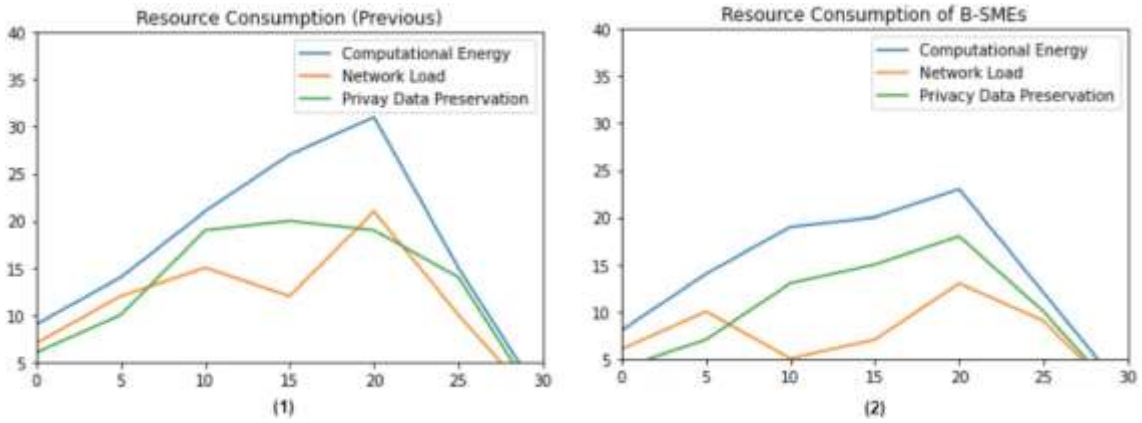

Figure 6 depicts the graphs of previous work and the suggested B-SMEs for the cost of resource usage.

Future direction

In this context, four distinct subsections are used to showcase the open study fields, two of which deal with the future potential of SMEs and the digitalization of society. Others are consequently built on the interaction between SMEs and their clients, enabling privacy, security, and automation issues through the use of industrial IoT, AI, and blockchain.

Blockchains and digitalization and scope of SMEs in the next decade

In order to construct all of their operations digitally, assure confidentiality, and achieve strong efficiency, numerous financial institutions are now investing their resources in the creation of blockchain infrastructure. SMEs and associated operations are more dependable as a result of the increased pace in the development of information communication technology and digitalization35,36. The system that was developed for this infrastructure management makes it easier for SMEs to handle reporting to top businesses and regulatory bodies and makes it more convenient to stop money laundering. The chain-like structure that the distributed ledger technology presents to the involved parties allows for the visibility of individual transactions and information exchange as well as the delivery of safe, seamless operations and the maintenance of logs (immutable storage).

Security and privacy of data scaling

The expense of privacy and security, as well as the scalability of data management, are emphasized as major obstacles when creating blockchain-enabled D-Apps. When processing SMEs transactions, the blockchain-based modular architecture works with AI technology to continuously stimulate distributed IPFS and incorporate transmission information from the involved SMEs and relevant stakeholders. This preserves ledger integrity, system provenance, and transaction traceability. In this way, regardless of who manages the operations, the appropriate individual SME may quickly review the specifics of financial development, new participants, business logs, and similar information. Between SMEs and the regulatory agency, there is no central authority or middleman that manually verifies and confirms a lot of transactions. As comparison to previous methods, the possibility of information transmission between

participating stakeholders being altered or falsified has decreased or nearly completely disappeared. The peer-to-peer connection of the blockchain's permissionless public network, however, also helps users avoid worries when sharing their operating logs with regulatory and compliance authorities.

Distributed SMEs transaction and automation

In the setting of B-SMEs, all data is managed and optimized in a decentralized consortium on a distributed basis, particularly in public ledgers utilizing block chain. As a result of this advancement, SMEs now share crucial information in a secure chain-like structure using a chronological sequence, such as registration credentials, sale and purchase data, the growth of financial assets, market fluctuations, startup values, and other information. 35,36. Core data from the relevant SMEs is recorded in a block chain distributed ledger and tracked in accordance with the requirements, such as projected business and employment growths, etc. These records are made available through the DApp using a block chain-based public permission less network environment, which enables access to these sensitive and associated facts for the participating SMEs to make a significant economic contribution. Yet, the most important problems are analyzing and limiting repetitious data records, which take more time to divide into distinct logs and require more computing resources to do. To address this issue, we provide consensus protocols and smart contracts (chain codes) to automate transaction verification and validation in line with the ledger records strategy.

Cross-platform and regulatory issues

The registration of startups, the interchange of financial transactions, and privacy, transparency in intercommunication, ledger maintenance in the centralized server-based preservation are only a few of the hurdles, restrictions, and problems related to the current SMEs. In order to manage and optimize data, it relies on third parties, who also provide security solutions. Also, there are several tools, methods, and apps that employ IoT technology to collect data from portable devices in order to handle these issues35,36. Use various ML approaches to examine and evaluate each log in order to find and eliminate redundancy in the ledger and improve it.

Conclusion

This study examines the current security and privacy practices and identifies the gaps that exist when SMEs are connected and transmit relevant information through node-to-node communication across a centralized network. In this research, we present a B-SME, a collaborative technological framework using block chain, IoT, and AI, which reduces the resource utilization of the collaborative technologies in the distributed network environment and improves the system's dependability and efficiency. This B-SMEs has created and deployed a secure process hierarchy of data management and optimization to be resource- and cost-effective, preventing any issues with the provenance of the system. Without affecting the block chain docker container, it upholds efficient data integrity and a transparent, traceable, and dependable environment. According to the experimental findings, information exchange between interoperable chains improves by up to 17.3% while using less of the system's processing resources (9.13%). Yet, compared to the existing system in place for SMEs, just 14.11 percent and 7.9 percent of B-SME transactions employ network bandwidth and storage capacity, respectively.

To do this, however, we developed three distinct chain codes (smart contracts) and tailored consensus rules (such as PoW and PoS) in order to automate and examine unique business transaction verification and validation processes. The consumption of resources, such as the price of computational energy, network load, and preservation, is decreased by B-SMEs in this way. The information of nodes is optimized and stored in IPFS with a block chain ledger during every transaction involving SMEs, and this is done in accordance with the protocol laid out in the chain code, which was created in response to the need for a data structure for streamlining broadcasting, content management, and transmission in general. In essence, two distinct distributed communication channels, such as on-chain and of-chain, are used to arrange and carry out all of these SME-related transmissions (financial, social, economic, etc.). On-chain communication, however, takes care of all implicit operations. Of-chain manages activities explicitly as a result. The experimental outcomes showed, in the end, that this suggested B-SMEs is a good option when applied in the real-time industrial context.

Data availability

Due to ongoing research on the same subject for futuristic solutions, the datasets created and/or analyzed during the current work are not publically available, however they are available from the corresponding author upon justifiable request.

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