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SURVEY

An Examination of Distributed and Decentralized Systems for Trustworthy Control of Supply Chains

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ABSTRACT Establishing a well-functioning Supply Chain Management (SCM) system is paramount during challenging times such as pandemics, natural disasters, and international conflicts. The complexity of global supply chains necessitates efficient systems, procedures, and personnel to ensure optimal results. Poor coordination among entities can lead to increased counterfeit products, increased ocean transportation costs, more expensive freight brokerage, bottlenecks in cargo flow, congestion, and complications in product accountability. To ensure a smooth and hassle-free operation, it's essential to maintain unambiguity and accuracy throughout every process. Therefore, it is vital to have effective systems, procedures, and personnel in place for SCM. The challenges encountered in SCM can be effectively tackled by utilizing blockchain technology. The architecture of blockchain technology is characterized by its distributed, decentralized and robust safety measures, which guarantee the integrity of data storage and its distribution across a meticulously organized ledger. Users can confidently rely on this innovative design's transparency, reliability, and safety. Implementing blockchain technology carries immense potential in bolstering safety and privacy measures in diverse sectors, including agriculture, healthcare, Goods and Services Tax (GST), academics, e-voting and automobile. This investigation delves into the practical applications of blockchain technology for SCM. It thoroughly analyses existing research and literature to uncover the latest advancements and potential future breakthroughs in this area.

INDEX TERMS Accountability, blockchain, counterfeit, distributed, decentralized, safety, supply chain management, unambiguity.

I. INTRODUCTION

The process of getting a product from the point of production to the end consumer involves a complex network of entities and steps. This network is referred to as the supply chain. Businesses employ supply chain management (SCM) approaches to manage the supply chain's flow of goods and services effectively. SCM is a comprehensive approach that involves coordinating the activities of multiple suppliers and customers to ensure that products are delivered on time and in the right quantities. To achieve this, businesses involved in the supply chain must disclose their stock levels to a central authority responsible for overseeing the entire process [1]. In the realm of SCM, it is common practice to adhere to a linear process. This approach is characterized by a sequential flow of stages, where the output of one stage serves as the input for the next. For instance, the manufacturer obtains raw materials from the supplier, which are then transformed into finished products. Any interruption in this prescribed order can lead to undesirable consequences throughout the entire supply chain network [2], [3]. Therefore, ensuring a seamless flow of operations is crucial for the success of any supply chain endeavour. However, traditional SCM methods and digital supply networks have been criticized for focusing solely on fulfilling supplier demands rather than meeting customer needs [4]. This approach can lead to inefficiencies and delays in addressing supply chain issues, negatively impacting customer satisfaction and overall financial gains. Managing supply chains has become increasingly complex and challenging for businesses and organizations, mainly due to the effects of globalization.

One of the key challenges businesses face when managing their supply chains is ensuring that they can adapt to the requirements of different markets. When companies expand

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their sales in international markets, their supply chains must undergo significant changes to accommodate the localization of products for consumers with varying cultural backgrounds and preferences. This can be challenging, as businesses must coordinate their corporate applications across multiple locations to ensure no inventory mismanagement [5], [6]. Quality control is another important factor that businesses need to consider when managing their supply chains. Quality and conformity are often interconnected in the production process, and companies are responsible for ensuring that their production, packaging, handling, and transportation of products comply with all relevant national and international regulations [7]. To ensure compliance with regulatory requirements, it is imperative for enterprises to carefully prepare the necessary documentation, which may include permits, authorizations, endorsements, security assessments, and standard control inspections. Managing supply chains is a complex and challenging task for businesses and organizations. To overcome various obstacles, manufacturers must manage and integrate data by linking their SCM systems with those of their suppliers and partners. This will enable manufacturers to gain valuable insights and control over their procurement, production, storage, and distribution activities [8].

Dealing with raw data from suppliers, partners, and customers can be difficult for businesses, as it often consists of structured and unstructured information. Proper management and integration of this data are essential in ensuring the smooth flow of information in various formats required by different SCM systems [9]. Effective data management and integration can help address SCM concerns at every stage and in every activity. This benefits manufacturers in terms of increased transparency and their suppliers and business partners. As cutting-edge technology like blockchain emerges, compliance monitoring and enforcement are also evolving. However, these developments will generate vast amounts of data that can overwhelm obsolete business software [10], [11]. Managers must evaluate which areas require such investments and seek software developers' advice to determine if the organization possesses the appropriate platforms for handling such data-intensive demands.

A. STRUCTURE OF THE SURVEY

An extensive and detailed examination of the topic will be presented in the following paper. The introduction in figure 1 gives readers a thorough understanding of the subject matter, followed by nine sections that make comprehension easier. Section I examines factors influencing diverse perspectives in SCM and highlights recent blockchain implementations. The traditional supply process and technologies used in SCM are explored in section II, section III delves into the evolution and architecture of blockchain, and section IV discusses the various tools used in blockchain technology. Section V explores the challenges that arise in traditional SCM. Section VI comprehensively analyses research articles

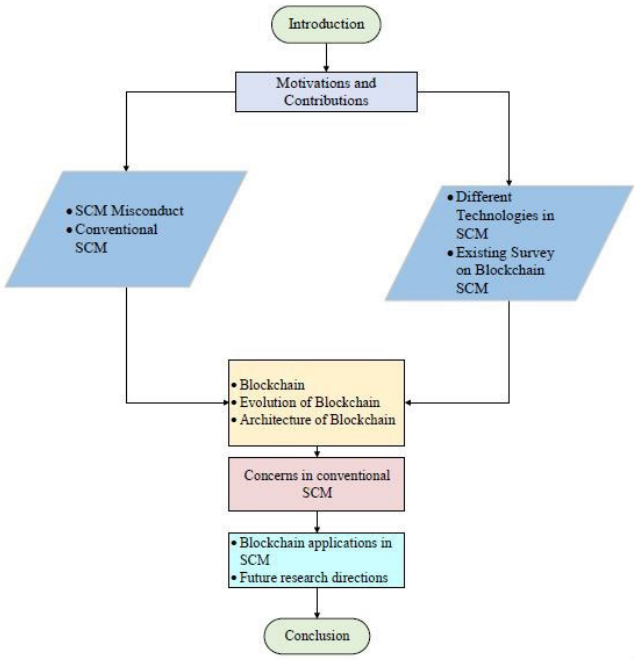

FIGURE 1. Organisation of the survey.

that focus on integrating blockchain technology into SCM, section VII discusses the scope for future research, and section VIII summarizes the survey's purpose.

B. MOTIVATIONS AND CONTRIBUTIONS

In today's dynamic and constantly changing global landscape, the effective management of supply networks has become a vital strategy for many industries. Ensuring transparency and traceability can be challenging, given the numerous parties and transactions involved. Furthermore, conventional supply chains encounter many obstacles, including the prevalence of counterfeit products, hazardous incidents, and disruptions, as well as their value in boosting confidence and maintaining positive credibility amidst unprecedented circumstances such as pandemics, inflation, war, and natural calamities. As such, businesses must prioritize developing and implementing a robust SCM system to succeed. By doing so, companies can reduce risks, improve operational efficiency, foster lasting relationships with suppliers and customers, and ultimately secure long-term viability.

Blockchain technology is renowned for its dependability, transparency, and traceability, which promotes trust. Unlike the conventional traceability techniques implemented by most distribution networks, blockchain technology does not necessitate central administration or any compromise on information security. The unalterable and decentralized nature of blockchain technology has piqued the interest of businesses. The extensive research aims to explore the various potential applications of blockchain technology within

modern supply chain networks. The main focus is to thoroughly examine the feasible use cases of blockchain in key sectors such as agriculture, food production, and healthcare. The primary objective of this study is to conduct a comprehensive assessment of the progress made in implementing blockchain technology in SCM over the last three years. The focal points tackled in this document encompass:

- We delve into the intricacies of SCM, exploring its motivations, contributions to the industry, and potential shortcomings.
- One area of focus is to examine misconduct in SCM, limitations in traditional supply chain practices, and various technologies of SCM.
- To explore the objectives, crucial components, constraints, and challenges associated with implementing blockchain technology in SCM, drawing on past studies.
- It is vital to acknowledge these concerns to address them effectively and move forward positively. Another crucial aspect we cover in detail is the evolution of blockchain technology. We thoroughly analyze blockchain architecture and consensus algorithms.
- Furthermore, to examine the available tools for blockchain and its application in the supply chain, highlighting this technology's unique benefits and future challenges.

Table 2 thoroughly examines the various SCM applications that utilize blockchain technology. The table offers a comprehensive analysis of the various ways in which blockchain technology can be used to improve SCM processes. It provides valuable insights into each application's potential benefits and challenges.

C. SCM MISCONDUCT

Considering the number of parties involved in SCM, dishonest dealings are inevitable. Digital supply chains incorporate current procedures, tactics, and technology. Digital supply chains use novel techniques, methodologies, and tools [12]. With the help of modern technological advancements, the latest supply chain has become more efficient. However, instances of misconduct still occur from time to time. Results from a study of 151 industrial supply chain workers show that insiders there believe their company loses about 9% of its annual revenue to interdepartmental dishonesty [8]. Product quality counterfeiting, pricing/invoicing dishonesty, and money laundering are often reported forms of deception in SCM. As reported by [13], one-third of the 1215 fish samples gathered from eateries, sushi shops, and supermarkets were incorrectly labeled or product counterfeited. Of them, 59% was escolar, an oil-rich fish that might induce keriorrhea comparable to diarrhoea. The adoption of synthetic polymer components by the sub-suppliers has compromised the operation of the accelerator arms, Aston Martin was forced to withdraw over 17,000 vehicles, about 75% of cars built between 2007 and 2012 [14]. In 2013, a crisis broke out in the food supply chain across Europe when it was discovered that goods labeled as beef contained horse meat, in some instances 100% [15]. As a result of globalization, modern food supply chains are more intricate, and it is standard practice for businesses to use third parties to handle their trading, manufacturing, shipping, and other operations. However, the supply chain's length and complexity heighten the potential for product fraud and distrust among its many participants [16]. The foreign items in the supply chain were likely intentional rather than unintentional based on the distinct differences between a cow and a horse. Therefore, traceability is essential across the entire distribution process, especially in the distribution chain for food products [17], [18]. Most

TABLE 1. Definitions of acronyms.

Acronyms	Definitions
AI	Artificial Intelligence
API	Application Programming Interface
BCT	Blood Component Type
BDA	Big Data Analytics
BUS	Blood Unit Status
BUR	Blood Unit Received
CC	Cloud Computing
COVID	Coronavirus disease
CRFH	Crop Ready for Harvesting
DIDs	Decentralized Identifiers
DApp	Decentralized Applications
ED	End Delivery
EM	Extraneous Material
EVM	Ethereum Virtual Machine
FDA	Food and Drug Administration Authority
GDP	Gross Domestic Product
GST	Goods and Service Tax
IDE	Integrated Development Environment
IoT	Internet of Things
IPFS	Interplanetary File Sharing System
JAVA	Just Another Virtual Accelerator
JSON	Java Script Object Notation
ML	Machine Learning
NASA	National Aeronautics and Space Administration
NBRC	Number of boxes ordered by the customer
NR	Not Ready
pBFT	Practical Byzantine Fault Tolerance
PoET	Proof of Elapsed Time
PoS	Proof of Stake
PoW	Proof of Work
PoX	Proof of Exercise
P2P	Peer to Peer
QB	Quality Bad
QG	Quality Good
Q2C	Quote to Cash
RBC	Red Blood Cells
RC	Refining completed
RD	Ready for Delivery
RFID	Radio Frequency Identification
RPA	Robotic Process Automation
RPC	Remote Procedure Call
SD	Start Delivery
SHA	Secure Hashing Algorithms
SCM	Supply Chain Management
TQ	Trade Request
TT	Tracking and Tracing
WCO	World Customs Organization
WHO	World Health Organization
WTO	World Trade Organization

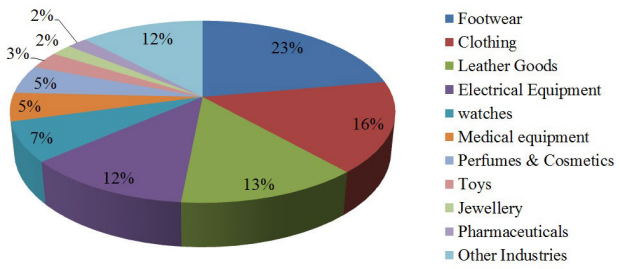

FIGURE 2. textbfWorld customs organization 2016 report on counterfeit products.

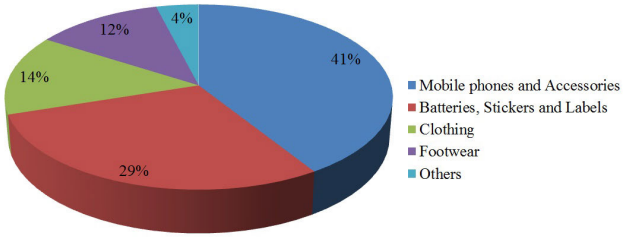

FIGURE 3. World customs organization 2022 report on counterfeit products.

shoppers want to know where their food was produced so they can make an informed decision about its safety. It was reported that a prominent supplier of aluminium to the National Aeronautics and Space Administration (NASA) has been faking documents and test results on aluminium strength and dependability for 19 years, prohibiting the satellites from being put into orbit despite a 700 million price tag and years of preparation [19].

Furthermore, during pandemics like Corona Virus Disease (COVID)-19, the healthcare supply chain lacked openness. A vaccine's quick release and the launch of a global boosters campaign are both crucial. Still, their efficacy will rely on the existence of a functional and visible distribution channel that all key players can verify [20]. Supply chain systems must keep track of where goods are at all times and serve as a point of exchange. There is an increase in network complexity because of the volume of transactions processed by these systems. Due to their centralized service structure, supply chains that enable financial transactions on their networks lack credibility and assurance. Centralized storage methods commonly experience inefficiencies in logistics systems because they cannot handle substantial amounts of data, consequently lowering the network as a whole [21]. The World Health Organization (WHO) asserts that up to 10% of transplanted organs may have been acquired through unscrupulous means, including the illegal trade of organs in healthcare supply chains [22]. However, the precise number of such incidents remains unclear due to a lack of transparency among the parties involved. This lack of transparency has created an environment in which illegal purchases and trades of organs can occur, along with medical professionals engaging in unethical practices [23], [24]. Regrettably, some medical facilities take advantage of the urgency felt by organ recipients by offering transfers to those who can pay the highest amount, regardless of their position on the waiting list. In addition to dishonesty in various sectors, between 2016 and 2017, there was an increase in the average number of automobile recalls in the United States from 30,000 to 90,000. This poses a potential danger as a faulty component could fail unexpectedly and lead to severe damage or even loss of life [25]. In a study by [26], 345 passenger cars in the United States were inspected for various issues in different automotive systems, such as electronics, steering, and fuel. It was discovered that half of the recalled cars had issues with crucial components and systems. Such incidents have a significant impact on the credibility and economic performance of a company.

According to reports from the World Customs Organization (WCO) [27], more than two million counterfeit items were seized during operations in 2016 and 2022; out of the seized items, the percentage against each item in the year 2016 is footwear 22%, clothing 16%, leather Goods 13%, electrical equipment 12%, watches 7%, medical equipment 5%, perfumes & cosmetics 3%, toys 3%, jewellery 2%, Pharmaceuticals 2%, other industries 12% as shown in figure 2. The operation's objective was to gather resources from customs administrations that participated and conduct simultaneous inspections of shipments that may have fake and/or pirated items. Additionally, the goal was to understand better the movement of goods entering Europe. Similarly, in 2022, the investigation authorities confiscated 2.3 million counterfeit items, which included 11 different types of pirated and fake goods, including mobile phones and accessories 41%, batteries, stickers and labels 29%, clothing 14%, footwear 12%, and others 4%, as shown in figure 3.

D. WORLD TRADE ORGANISATION (WTO)

According to recent predictions by WTO experts, global trade growth in 2023 is expected to remain below average despite a slight improvement in Gross Domestic Product (GDP) projections since last fall. The global merchandise trade saw a meagre upswing of 2.7% in 2022, which was impeded by a steep decline in the final quarter. This year, it is estimated to increase by 1.7%. In 2022, there was indeed an uptick of 2.7%, but regrettably, it was followed by a severe downturn in the final period. Based on the latest assessments, there is a projected increase of about 3.2% in trade expansion by 2024.

Furthermore, the GDP is expected to grow by approximately 2.6% [42]. However, it is important to acknowledge that the forecast is not entirely certain due to the presence of several risk factors. These risks include the possibility of international conflicts, unexpected disruptions in supply chains, and the likelihood of unforeseen consequences resulting from more restrictive monetary policies. Therefore, it is crucial to closely monitor these factors and their potential

TABLE 2. A review of recent articles on blockchain SCM.

Survey	Objectives	Important Components	Constraints	1	2	3	4
Matteo Fiore.et.al. 2023 [28].	• The objective of this paper is to illustrate the potential of blockchain technology in alleviating the supply chain obstacles encountered by the healthcare sector.	• Implemented the proposed model in consortium blockchains using designated nodes to oversee consensus.	• Improvements in patient outcomes and healthcare efficiency can be achieved using blockchain technology. • Additional comprehensive research studies, accompanied by practical applications, are necessary.	✓	✗	✓	✓
Jianting Xia et.al. 2023 [29].	• The authors aimed to give a case study of Lenovo, an elite business using blockchain technology, to clarify the benefits of doing so.	• Information from a supply chain's application, contract, and data layers are unified in this architecture.	• It may be beneficial to comprehend blockchain's potential applications in logistics contexts and its inherent logic.	✓	✓	✗	✓
Md.Ariful Islam.et.al. 2023 [30].	• This study suggests utilizing a distributed application to strengthen communication and collaboration.	• This software boasts multiple user interfaces that effectively cater to diverse user needs.	• Utilizing hyper ledger fabric is an extremely arduous and time-intensive undertaking.	✓	✗	✓	✓
Maria-Victoria Vladucu.et.al. 2023 [31].	• The study highlights the potential of blockchain technology in addressing the reliability and security of electronic voting systems.	• Effectively developed decentralized programs on the ethereum platform. • Constructed blockchain applications on ethereum, truffle.	• The proposed model must integrate everyone to vote via a decentralized electronic voting system.	✓	✗	✓	✓
Lovina Yogarajan.et.al. 2023 [32].	• This study seeks to investigate how blockchain technology could benefit the farming and food industries by improving product monitoring, assuring food security, and lowering the deterioration of food.	• The research shows five phases of adoption: the stragglers, the late majority, the early majority, clients and customers.	• To gain more insight, it would be beneficial to review the literature systematically.	✓	✗	✓	✓
Udit Agarwal.et.al. 2022 [33].	• This report analyzes the current studies regarding blockchain functionality, use cases, and commercial results across multiple SCMs.	• A comprehensive research and analysis of blockchain incorporation into SCM was conducted. • Exploring publications in academic journals and databases inspired this study.	• For effective SCM using blockchain, collaboration, cooperation, and utilizing appropriate consensus procedures are essential. • It is necessary to have a diverse range of robust consensus algorithms and techniques to enforce security measures.	✓	✗	✗	✓
Diana Hawashin.et.al. 2022 [22].	• The authors aim to facilitate a decentralized, secure, traceable, auditable, private, and trustworthy organ donation and transplantation administration system.	• Participants can interact with the smart contract's features through Decentralized Applications (DApp) linked to the contract via an Application Programming Interface (API).	• Developing a full-fledged DApp may be a viable option for future solution developments.	✓	✗	✓	✓
David L. Cortesmurcia.et.al. 2022 [35].	• This study presents a conceptual framework synthesising the connections between pertinent disruptive technologies, physical internet concerns, and essential supply chain activities.	• They proposed a five-step procedure that should be strictly followed during a systematic review.	• When looking for sources, it's recommended to focus on articles published in academic journals and book chapters rather than conference papers, which may only touch on emerging trends.	✗	✗	✓	✓

1: Use cases 2: Classification 3: Utensils 4: Open Issues ✓: Discussed ✗: Not Discussed

TABLE 2. *(Continued.)* **A review of recent articles on blockchain SCM.**

Pratyush Kumar Patro.et.al. 2022 [34].	• This paper aims to develop a method for managing the fishing supply chain using the ethereum blockchain.	• This study employs a system architecture and sequence diagrams to describe the fisheries supply chain.	• The authors plan to concentrate on creating DApps that are attractive to a broad range of people.	✓	✗	✓	✓
Bhutta.M.et.al. 2022 [36].	• The article delves into the review of blockchain technology to efficiently manage and organise SCM securely.	• The user-friendly interface of the model provided ample opportunities for interactive usage, enabling seamless query operations that were both complex and intricate.	• When addressing the matter of scalability, it is crucial to conduct thorough research. Scalability issues can be addressed as future research directions.	✗	✗	✓	✓
Khan.et.al. 2022 [37].	• In light of the COVID-19 pandemic, a study has been conducted to explore the potential use of blockchain-based technologies for the supply chain of agricultural products.	• Conducting interviews with various businesses operating in Pakistan's agricultural sector.	• The number of interviews conducted was lower than desired, and necessary steps must be taken to prevent this from occurring in the future.	✓	✗	✓	✓
Li.Z.et.al. 2022 [38].	• In order to guarantee a safe platform to facilitate information retention, the authors suggest a healthcare system that makes use of blockchain technology.	• The authors enhanced safety measures by utilizing re-encryption proxies and kept a hash value of the record.	• It is within the realm of possibility that the approach being proposed may utilize a white-box methodology, which involves a transparent and inspectable system where the internal workings and processes are visible and accessible for analysis.	✗	✗	✓	✓
Diana Hawashin.et.al. 2021 [39].	• This paper aims for a decentralized, open, easily identifiable, verifiable, private, secure, and trustworthy network management of blood donation via a private ethereum blockchain.	• The authors have developed sequence diagrams, two smart contracts, and algorithms to incorporate features and conduct security analyses.	• Future plans include deploying and testing the developed smart contracts on the live ethereum network and developing a full-fledged full-stack DApp using Web3.0.	✓	✗	✓	✓
Ilhaam A. Omar.et.al. 2021 [40].	• The writers of this study aim to suggest a blockchain-based method for inventory sharing that would connect distributors and merchants.	• The system exploits ethereum's shared storage and building of smart contracts for its own ends.	• The authors advise developing DApps to streamline crucial supply chain processes that impact all parties.	✓	✓	✗	✓
Ahmad Musamih.et.al. 2021 [41].	• The article aims to develop an efficient healthcare product tracking approach using intelligent agreements and to check the vulnerability through security analysis.	• The involvement of interested parties and their interactions with the smart contract was monitored.	• Future research aims to enhance the effectiveness of pharmaceutical supply chains.	✓	✗	✓	✓
Vinoth Kumar.C.et.al. 2023.	• The main aim of this research is to thoroughly investigate the numerous potential applications of blockchain technology in the sphere of SCM. • By examining the various ways, we hope to understand better how it can be leveraged.	• Through thoroughly examining existing research and literature, the authors have uncovered the most recent and cutting-edge developments being employed in decentralized systems. • This comprehensive analysis provides valuable insights into the latest advancements in this field.	• Researchers can benefit from the highlighted key takeaways that can guide future research directions.	✓	✓	✓	✓

1: Use cases 2: Classification 3: Utensils 4: Open Issues ✓: Discussed ✗: Not Discussed

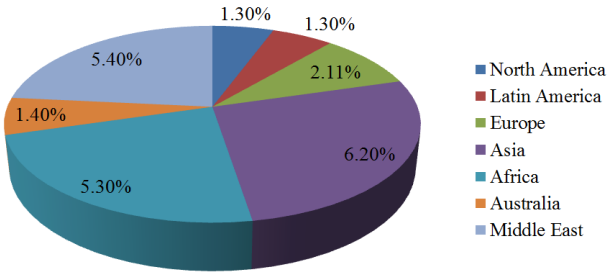

FIGURE 4. WTO forecasts percentage of increase in trade (2016-2026).

impact on the economy. Figure 4 highlights that the WTO predicts rising global exports. Based on the comprehensive data provided by the WTO, the growth of exports in Asia shows an impressive surge, leading the way in the global market with a significant share of 6.2%. Middle eastern countries are also making a noteworthy contribution to the global export market, holding a share of 5.4%. Additionally, Africa's export industry is also making a considerable impact, recording a market share of 5.3%. Meanwhile, Australia recorded a share of 1.4%, and the Americas have experienced a moderate rise in their export industry, holding a market share of 1.3%. These numbers reflect the ongoing efforts of these regions to enhance their competitiveness and establish themselves as key players in the global export market. According to WTO, the black market for pharmaceuticals accounts for between 1.3% and 4.2% of all international trade in the field [43]. Attempts to employ cutting-edge technology, especially blockchain technology and computational intelligence, to protect and strengthen customs and government agencies control the establishment of new e-commerce regulations, including those being debated during the WTO collaborative programme on online commerce.

E. COUNTERFEIT MEDICINAL PRODUCTS

WHO issued a medical product alert after discovering two tainted items in Uzbekistan on December 22, 2022. As they fall short of expected quality requirements, these items are deemed "out of specification".

- In February 2021, a fake COVID-19 vaccine with the lot number "BNT162b2" was found in Mexico. The WHO has confirmed that it is indeed fake. Patients received this fake vaccine from sources outside official immunization programs.
- Similarly, in February 2022, WHO received notification about the contamination of two batches of DESREM Remdesivir for injection of 100mg/vial. These storage units were located in Guatemala and India.
- According to the WHO medical product alert, two counterfeit VITAMIN A (retinol) pills were found in Chad and reported to WHO in November 2020.
- Table 3 highlights the report of the WHO, which listed the manufacturer against counterfeited medical products from the year 2021-2023 [44].

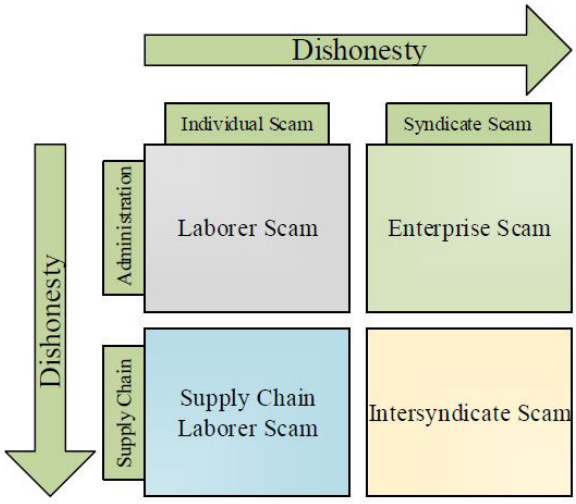

FIGURE 5. Various levels of misconduct in SCM.

Hence, the topic of fraud in accounting and auditing has received significant attention in the literature, with a recent focus on how fraud may affect supply chains. Studies show an increase in supply chain fraud, but academic research on the topic remains limited. Some publications geared toward industry professionals have explored the impact of supply chain fraud. However, there is a lack of literature specifically on supply chain fraud, though there is potential for research in the field of supply chain ethics [45], [46].

It is evident from the survey that dishonesty significantly impacts the supply chain process. Misconduct is a significant concern in the supply chain but is often disregarded [47], [48]. Nonetheless, vulnerabilities do exist, and it is crucial to identify them early through proper procedures and technology to mitigate the lasting effects of fraud in the global supply chain. The survey undertaken for this study uncovered several instances of supply chain scams, as shown in figure 5. Executives often cite incidents of quality control scams, pricing/invoicing scams, and bribery as the most prevalent types of inter-organizational misconduct [49], [50], [51]. Due to the purposeful nature of inter-organizational misconduct, the approaches to identifying and controlling the associated risk vary significantly from those studied in traditional risk management literature. Risks may be amplified, for instance, when inventory management is used to safeguard against disturbances. Illicit activity studies need to consider the underlying motivations and actions contributing to fraud since the nature of the risk differs based on the fundamental motivations [52], [53], [54].

- Bad business practices, poorer monitoring standards, and inadequate levels of scrutiny and detection have all been connected to opportunities for misbehaviour [55], [56].
- Factors such as financial goals, pay scales, company setbacks, and market saturation may all contribute to a

TABLE 3. Report on counterfeit medicinal products by WHO.

Counterfeit Medicinal Products		
Year	Manufacturer	Product
2023	Galentic Pharma (India) Pvt. Ltd	Tetracycline Hydrochloride Ophthalmic Ointment 1%
2023	Marion Biotech PVT. LTD	AMBRONOL syrup
2023	Marion Biotech PVT. LTD	DOK-1 Max syrup
2022	Celon Laboratories, PVT LTD	METHOTREX 50mg
2022	PT Konimex	TERMOREX
2022	PT Yarindo Farmatama	FLURIN DMP
2022	PT Universal Pharmaceutical Industries	UNIBEBI COUGH SYRUP
2022	PT Universal Pharmaceutical Industries	UNIBEBI DEMAM PARACETAMOL DROPS
2022	Astra Zeneca	DIPRIVAN 10mg/ml
2022	IPSEN	Dysport 500U
2021	Mylan Laboratories Ltd	DESREM
2021	ALEXION	SOLIRIS 300mg
2021	Strides Arcolab Ltd.	Lumefantrine Tablets (20/120mg)
2021	Astra Zeneca	COVID-19 Vaccine Astra Zeneca
2021	PFIZER	Pfizer-BioNTech COVID-19 Vaccine
2021	PFIZER	CYTOTEC 200 microgram tablets
2021	PFIZER	COVID-19 Vaccine BNT162b2
2021	Banner Pharmacaps (Canada) Ltd	VITAMIN A (RETINOL)
2021	Accucaps Industries Limited	VITAMIN A (RETINOL)

sense of urgency or pressure that leads some people to resort to scam practices.

- A supplier's likelihood of engaging in illicit behaviour increases if they believe they can commit and hide the misconduct from a customer.
- When suppliers are under severe hardship, they may feel compelled to resort to dishonest practices to sustain profitability, enhance revenue, or even hold off bankruptcy.
- Authors of [57] hypothesize that increased levels of supply chain pressure would result in more instances of misconduct between companies.
- Fraudulent activities such as bribery, counterfeiting, money laundering, and false payments can occur at any stage of the supply chain. Corruption within organizations also poses a threat.
- It's possible that businesses dealing with intense levels of competition may make less moral decisions to deal with the temporary constraints they're under.

As per the authors, it is advisable to review the chain of command within the organization to mitigate these risks. To lessen the likelihood of scams occurring, it is vital to provide adequate balances and checks and to enhance the monitoring of independent parties. As Katz [58] argued, supply chain misconduct is less likely to occur when there is more electronic integration between all of the supply chain systems.

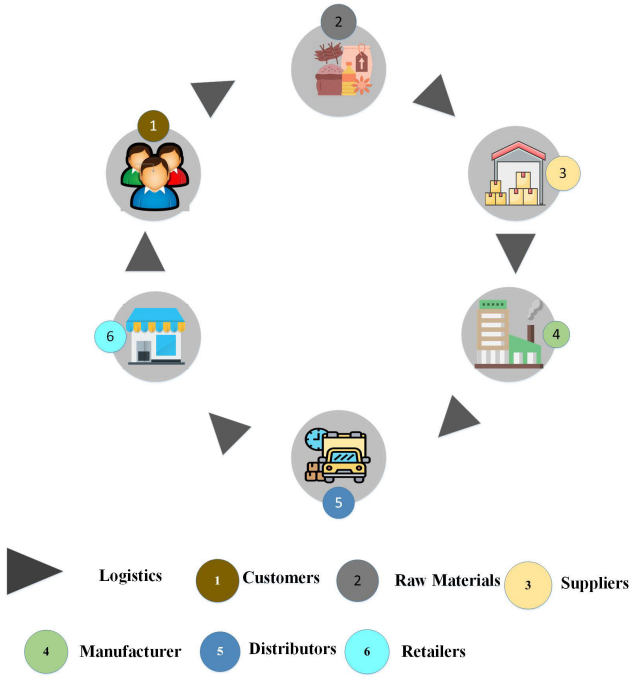

FIGURE 6. Traditional methods of managing supply chains.

II. TRADITIONAL SUPPLY CHAIN

The supply chain consists of all the interactions between suppliers, manufacturers, distributors, retailers, and customers that lead to the final product being used by the customer, as shown in figure 6. Effective SCM is a crucial process that empowers companies to regulate the movement of goods and services among their stakeholders. In the realm of SCM, the traditional approach is to follow a structured framework that operates hierarchically [59], [60]. This framework commences with the clients' orders, which serve as the basis for determining the product demand. The demand is then processed into manufacturing feeds, which trigger the production phase. Once the production process is complete, the goods are then shipped and distributed to various retailers. The regional offices act as the central decision-making hubs, collecting, analyzing, and disseminating data to the concerned parties. However, this model has various inherent

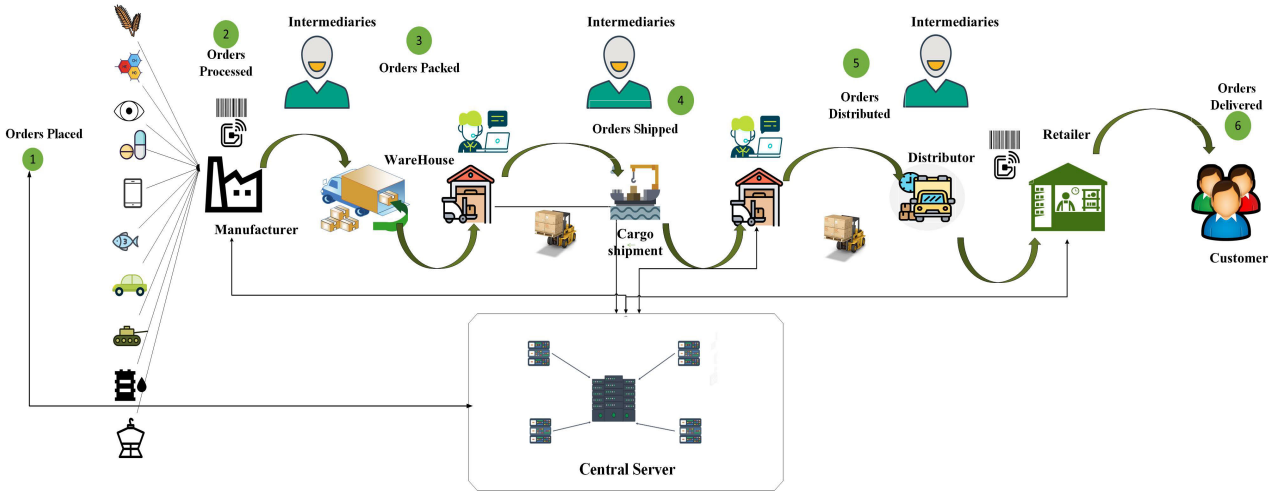

FIGURE 7. Understanding the transit of goods and services within the supply chain.

issues that can negatively impact the supply chain [61], [62]. For instance, it lacks transparency, traceability, and stakeholder involvement, leading to insecurity and instability. Our current supply chain has undergone a significant shift towards centralization, which can be viewed as advantageous in terms of convenience. The diagram provided in figure 7 exhibits the prevailing centralization that defines traditional SCM systems [63], [64]. This model revolves around a centralized office and warehouse, which professionals with specialized knowledge in logistics, distribution, and procurement manage. These managers oversee and operationalize the day-to-day activities within their respective supply chain segments. A centralized database is utilized to facilitate the collation and management of data. However, while this approach has proven to be efficient in certain regards, it has drawbacks. One of the key challenges often encountered in this model is the potential for covert misrepresentation of company data. This is particularly concerning in cases where such misrepresentation could harm the business's expansion efforts. Such issues can lead to growing mistrust between businesses, increasing communication costs [65].

Furthermore, the presence of intermediaries within the supply chain can hinder the effective and transparent pricing of goods and services. Data incompatibility is often among the various entities that make up the supply chain. This can make tracking and managing product movement difficult, leading to delays and other challenges [66]. The potential for data manipulation within the supply chain is a primary concern. It can lead to significant challenges and delays in the product tracking process, which can negatively impact the efficiency and profitability of the business. However, it also gives rise to many challenges that cannot be overlooked. One of the primary concerns is the high costs associated with managing a centralized supply chain, which can impact the pricing of products in the market [67], [68], [69]. The lack of helpful market analysis features in such a system can make obtaining insights that can help optimize the supply chain network difficult. Another significant issue that needs to be addressed is the lack of transparency and traceability in the current supply chain design. The present supply chain system has various difficulties, such as coordination, control of stocks, reliance on staff members, order supervision, stock administration, end-of-life control, and more. These issues can significantly impact stakeholders and consumers, making it challenging to assess demand and maximize production and storage capacity [70], [71].

The conventional SCM model is susceptible to issues such as product counterfeiting, delays, and fraud, which can have far-reaching consequences. As such, there is a pressing need to address these challenges and create a more efficient and effective supply chain network that benefits all parties involved [72], [73]. As such, there is a growing need for more sophisticated SCM systems that can help address these challenges and ensure greater transparency and accountability throughout the supply chain. Therefore, companies must adopt a more comprehensive approach to SCM that involves all stakeholders at every stage of the process to ensure a fair, transparent, and secure supply chain [74].

A. DIFFERENT TECHNOLOGIES IN SCM

The authors of [75], [76], and [77] have emphasized the significance of electronic integration in the supply chain. When new technologies promote innovation in supply chains, enterprises, labourers, and clients all win. Since we now live in a globally interconnected world, groundbreaking innovations that seek to strengthen the endurance and resistance of operations are now on the rise. The supply chain is digitally connected using the following technologies.

1) INTERNET OF THINGS (IOT)

The IoT is a network of connected devices that gather and transmit data without human intervention. The IoT advent has revolutionized SCM. Understanding where items are kept, how they are stored, and when they may be expected at a specific location has come a long way. This implies that

technologies like Radio Frequency Identification (RFID) may be used as part of the IoT to give inanimate things the ability to sense and respond to their surroundings [79], [80]. The IoT is understandably alluring, given its potential applications across the whole supply chain. The results help firms increase output, decrease downtime, better predict customer wants and requirements, and increase return on investment [81].

2) ARTIFICIAL INTELLIGENCE (AI)

Machine Learning (ML) and AI systems can help businesses predict changes in customer demand. AI can potentially lessen the impact of misconduct and pandemics on the supply chain. The supply chain as a whole may benefit from digital technology's ability to facilitate real-time data exchange among its many components [82], [83]. Supply chain managers can use AI-driven forecasting tools to streamline processes and save costs. Industry 5.0's AI and ML algorithms require data to ensure supply chains can withstand disruptions. IoT is crucial in building supply chain resilience by enabling the exchange of information, which enhances collaboration and visibility during troubles. These centralized technologies are integrated into business systems to provide real-time reporting, interactive data visualization, and higher intelligence levels [84], [85]. Improved scheduling and choice-making tools, the detection of purchasing trends, and the automation of time-consuming warehouse chores are all made possible by forecasting analytics and ML-based techniques [86].

3) BLOCKCHAIN

Blockchain profoundly affects contemporary civilization with its revolutionary transparency, decentralization, and security qualities. Blockchain attracted substantial interest due to its first implementation of cryptocurrencies [20], [87]. Blockchain technology is poised to revolutionize society and the corporate world in the not-too-distant future. In recent years, academics, business people, and researchers have studied blockchain as a new technology. This technology has the potential benefit of eliminating the need for a central authority to validate transactions; instead, the nodes linked to each block execute this function for each other. Blockchain is an extremely effective and safe way to preserve facts in autonomous sections [63].

4) CLOUD COMPUTING (CC)

Clouds are centralized storage and processing environments for many types of data and information [35], [88]. CC is the practice of storing and processing data over an external network of servers, as opposed to a local network. The supply chain may be impacted in several ways by CC. Using CC as an attractive supply chain application, these systems collect sensor data, process and examine it, and then present it to consumers in an intelligible internet-based depiction. The use of the cloud in the supply chain has several advantages. The biggest advantage of CC is probably its intelligence and automation [89]. CC analytics might completely revamp the supply chain. Insights on supply chain possibilities will be made available through cloud platforms.

5) BIG DATA ANALYTICS (BDA)

Big data refers to an abundance of data sets too large to be easily managed by conventional means. Data is being produced at a dizzying pace from the millions of data sources available today. These information hubs may be found all around the globe [90]. BDA may be divided into four categories: descriptive, diagnostic, predictive, and prescriptive. BDA has matured into an indispensable resource for businesses of all sizes and in all sectors. By using big data, companies may learn things about their clients and operations with the help of centralized architecture. BDA is a rapidly developing topic. Thus, in the future, it is anticipated that more incredible and game-changing uses for this cutting-edge tool may be possible. Risk management, new product development, improved internal decision-making, and happier customers are just a few areas where BDA may be used [91], [92].

6) ROBOTICS PROCESS AUTOMATION (RPA)

Faster and more precise processes with less room for human mistakes are made possible with the help of robots in the supply chain. Compared to human workers, robots excel in reliability and output [93], [94]. Robots do not take human jobs but supplement human labour to boost efficiency. RPA is helpful for businesses in many ways, including generating bulk emails, extracting data from media like Portable Document Formats (PDFs) and images of documents, generating and delivering invoices, verifying employee backgrounds, and automating payroll. Since the goal of every organization is to make a profit, RPA is especially useful in the Quote to Cash (Q2C) phase since it streamlines and improves sales processes. RPA may not work as advertised or provide the same results for each business. Additionally, many companies lack the skills and experience necessary to use RPA effectively. RPA is bound to fail if the project's timeline, budget, resource needs, and other restrictions are poorly understood.

III. EVOLUTION OF BLOCKCHAIN

As shown in figure 8, the early 90s marked the debut of both distributed ledger technology and digital currency. A chain of blocks that is secured is not a new concept. Stuart Haber et. al. proposed it in 1991 [95] to prevent the manipulation of electronic documents. A field of study concerned with making information sufficiently secure so it can be transmitted between two or more untrusted nodes. Information can be encrypted with a cipher and decrypted with a secret key. In 2009, Satoshi Nakamoto unveiled bitcoin, a decentralized digital currency based on blockchain technology [96]. As disruptive technology gained popularity in 2012-2013, it was implemented in e-commerce platforms, leading to the development of smart contracts and their

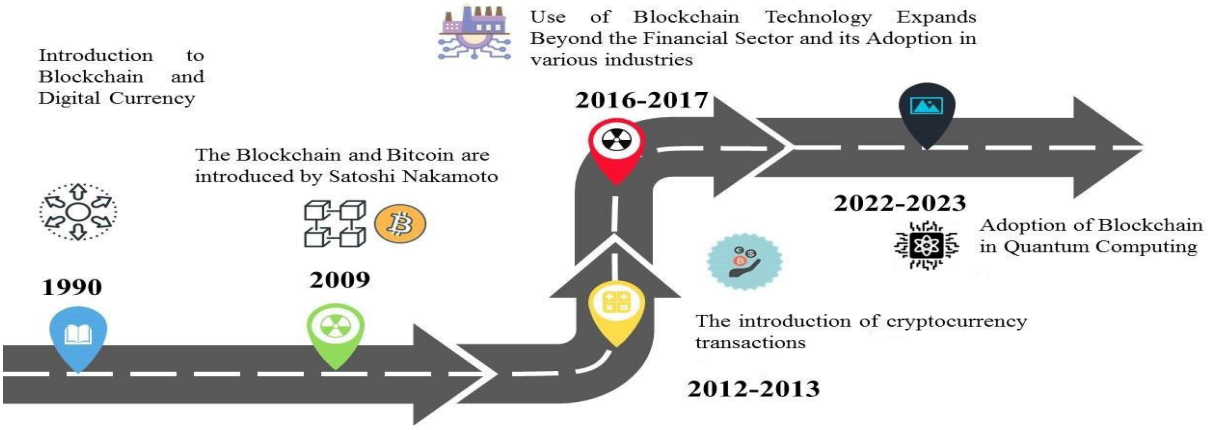

FIGURE 8. The advancement of blockchain technology.

application in non-monetary financial sectors in the following years. Due to the reliable nature of blockchain, in recent years, blockchain technology has been leveraged in securing quantum data. There are three types of blockchain: public, private, permission, and consortium [97].

In a public blockchain, transactions and data are viewable by all participants. Some popular cryptocurrencies developed on the public blockchain are bitcoin, ethereum, dash, factom [98]. Anyone can participate in the operations of a public blockchain like bitcoin. However, it requires significant computational resources, lacks transaction privacy, and has inadequate security measures. In a private blockchain network, one firm governs the network on behalf of its clients by establishing rules for participation, managing the consensus mechanism, and updating the distributed ledger. In a private blockchain, all participants are known to one another and belong to the same organization. Thus, all transactions are private; only the administrator may see them [99]. A few examples of private blockchains are multichain and block stack. In permission blockchain, Only certain members may see transactions, making them somewhat private. All players have been identified, and their profiles have matched their real-world counterparts. Some of the permission blockchains are hyperledger, r3, and ripple. Several businesses come together to manage a shared blockchain. For this blockchain, a small group of trusted parties manages all transactions and access to the ledger. When all participants in the consortium need access to the blockchain and will be responsible for its upkeep, a consortium blockchain is the best choice [100].

A. ARCHITECTURE OF BLOCKCHAIN

Blockchain is a virtual ledger that stores events as a collection of confidential blocks of information. The encrypted transaction data and the previous block's hash are stored in what is called a "block." A chain is similar to an endless series of linked blocks. The block comprises a header and a body, as seen in figure 9. Each block also includes the hash value of

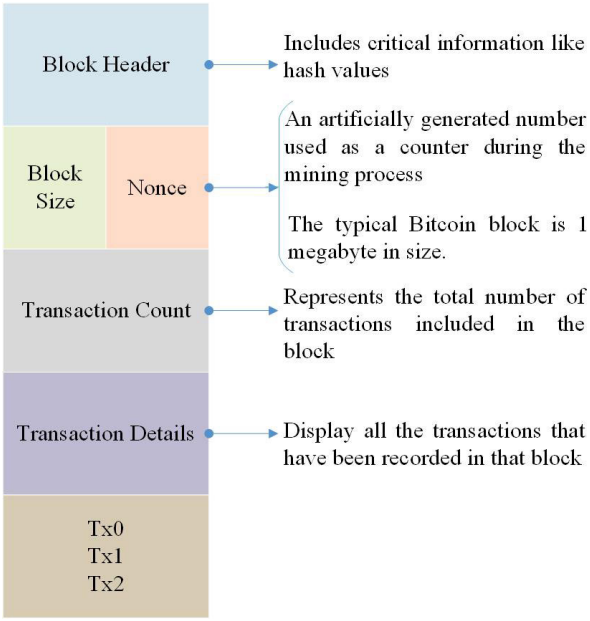

FIGURE 9. Understanding the components of a block.

the two blocks that came before it and the one that will come after it, if any. In this context, "public," "distributed," and "decentralized" all refer to the characteristics of blockchain. It is a distributed ledger that is cryptographically secure, append-only, immutable, and may be updated by mutual agreement among its nodes [97]. The term "blockchain" may be broken down into its constituent parts, block and chain, as seen in figure 10. As shown in figure 11, the merkle tree is a powerful data structure that easily maintains the integrity of enormous volumes of data. A binary hash tree is another name for this structure. The block header consists of four parts: the previous block's hash, the merkle source hash, the block version, and the timestamp of its creation. The body comprises the nodes' recorded transaction log and

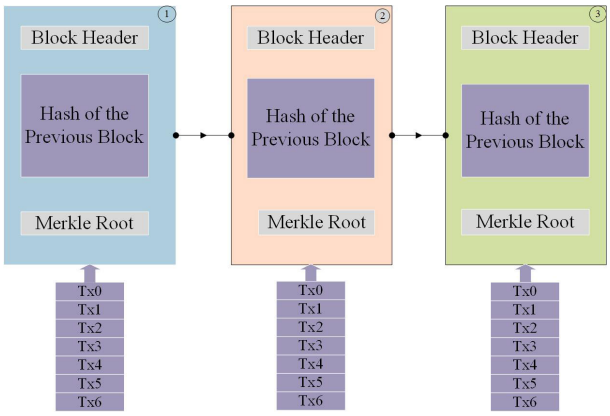

FIGURE 10. An example of a network utilizing blockchain technology.

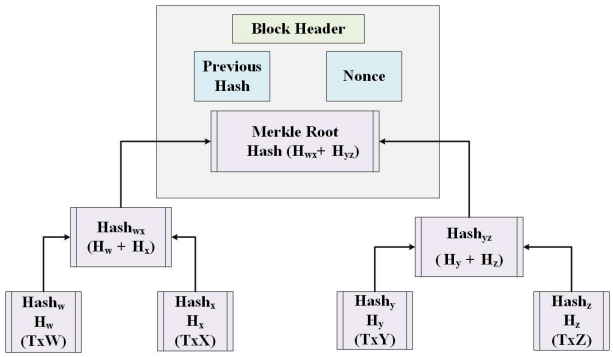

FIGURE 11. Binary hash tree in blockchain.

the nonce generated by the miner. A chain is like a long list of blocks that are all linked together. The hash values of the two blocks immediately before and following it in the chain are stored in each block. The process entails looking for a value that produces a hash starting with zero bits when hashed using a Secure Hashing Algorithm (SHA)-256. The algorithm verifies node transactions and creates new blocks for the blockchain. Merkle trees are advantageous because they validate data quickly and easily, reduce the amount of information required for verifying it, and require less memory altogether. To reach a consensus, nodes must overcome their mutual mistrust and agree on a stable data state. Several algorithms may be utilized to reach an agreement, which are as follows [101].

- Proof of Work (PoW).
- Proof of Exercise (PoX).
- Proof of Stake (PoS).
- Proof of Elapsed Time (PoET).
- Practical Byzantine Fault Tolerance (pBFT).

PoW verifies transactions and generates new blocks for the blockchain. Typically, verification involves running a single hash, and the amount of work required increases exponentially with zero bits. In PoW systems, miners compete for rewards by solving network transactions. Since PoW relies on the testing of millions of calculations per second on the supercomputers of miners, it is both expensive and energy-intensive to run. The PoX technique is a new and advanced method suggested to replace the traditional PoW approach in mining. In contrast to PoW, which involves solving intricate computational puzzles, PoX requires miners to solve complex matrix-based puzzles that are based on genuine scientific problems [102], [103]. System personnel meticulously choose and provide these problems to ensure their authenticity. This innovative approach has the potential to completely revolutionize the mining process by combining technology with scientific research. With PoS, users may mine and verify transactions depending on the number of coins they own while using a computationally cheap and energy-efficient mechanism. When using PoS, miners only get financial rewards from transaction fees. There is no competition for mining since the algorithm decides who will create each new block depending on the participants' stakes. To reach a consensus, PoET is another algorithm, which is a lottery-based agreement system designed to limit resource and power usage. Blockchain networks with restricted access can choose block winners and allocate mining privileges [104]. pBFT is the consensus method of choice for routing Peer-to-Peer (P2P) communications with as little delay as possible. The pBFT algorithm was carefully crafted to tackle the challenge of byzantine failures in asynchronous networks. It has undergone thorough testing and demonstrated remarkable proficiency in replicating state machines while considering distributed file systems and utilizing byzantine fault tolerance. The authors of [103] have expressed their confidence in its exceptional effectiveness, which speaks volumes about the algorithm's potential.

B. FEATURES OF BLOCKCHAIN

Table 4 highlights blockchain features, including high availability, transparency, security, cost-efficiency, and immutable. The significant disadvantages of the centralized database, when compared with features of blockchain, are that it is possible to falsify data, read it, and update and delete it. Meanwhile, since blockchain is a decentralized architecture, only append operation is possible. The data in a decentralized architecture is also completely immutable under ideal conditions. With the help of these features, blockchain can be deployed to centralized architecture to overcome its disadvantages.

IV. TOOLS

Many applications within the field of network technology have been crucial in protecting the honesty of commercial deals. These programs have been developed carefully to guarantee that all network activity is above board. These solutions, made possible by cutting-edge technology, have given businesses the resources they need to keep their networks reliable and secure, allowing them to focus on their primary activities and easily achieve their goals. Researchers have employed various techniques, tools, and models to construct blockchain systems [105].

TABLE 4. Typical characteristics of blockchain.

High Availability	• Despite 90% of nodes being down, a network can still function. • It is possible to find competitors anywhere.
Increased trust and transparency	• Nothing is hidden from the users, and any participant can view and validate the data; hence, it is highly transparent.
Data Privacy and Security	• There is no unencrypted data on the network. • Participant identity can be kept anonymous. • In place of sensitive data, only its hashes are stored.
Low transactional charges	• No organization is in charge of keeping the network running. • Despite the higher cost associated with decentralized alternatives, utilizing a decentralized system remains a more cost-effective solution than relying on a centralized one.

A. ETHEREUM

One such system is the organ donation system created by Diana Hawashin and her team, which is detailed in reference [22]. This system utilizes the ethereum and Interplanetary File Sharing System (IPFS) networks to ensure maximum confidentiality and safety. Ethereum has emerged as a leading blockchain platform due to its extensive features, public availability, and autonomous design, allowing it to carry out smart contracts exceptionally well. Ether, the system's native cryptocurrency, is the driving force behind everything it does. Importantly, Ethereum was built to work with public networks from the ground up, making it a highly adaptable, accessible to everyone, and blockchain-friendly platform. Intelligent agreements, which are simply shortcodes that allow the software, constitute the platform's defining characteristic. This function is crucial for keeping tabs on your finances. The platform uses the PoW technique to generate new blocks in a chain to maintain the blockchain's safety and transparency. In sum, ethereum is a state-of-the-art platform that might dramatically alter how we transact business online and engage with the virtual world [106], [107].

B. TRUFFLE

The Ethereum Virtual Machine (EVM) has undoubtedly become one of the most versatile and widely used tools in the blockchain industry. Its multifaceted capabilities serve many purposes, from blockchain examination to application development and resource management. Its immense popularity is evidenced by the fact that it has been downloaded over 1.5 million times and is extensively used for building blockchain-based applications. One of the most remarkable features of the EVM is its smart contract management capability. This feature is unparalleled in providing complete management of smart contracts, including testing and automatic deployment on the network and user interface. The smooth integration of the SCM system [108] with the smart contracts embedded in the distributed ledger technology necessitated the creation of a truffle interface, which ensures seamless communication between the two systems.

C. GANACHE

Regarding DApp development, one tool stands out above the rest: Ganache. Ganache, a blockchain platform, was developed with privacy as a top priority. It is commonly used for the safe creation of DApps. Ganache's software is user-friendly because it has a graphical user interface and a command line interface. In fact, many developers consider it to be the ultimate solution in this field. Its advanced features and capabilities give it a distinct advantage over other platforms, such as Remix [109].

D. METAMASK

Metamask is a fantastic option for anyone looking for a secure environment in which to keep and trade ethereum-based currency. This web-based wallet is a central point for communicating with many distributed programs. Metamask's ability to create unique mixtures of words that serve as login credentials constitutes one of its most striking features. This function offers a safer replacement for simple passwords, making your digital possessions more secure. Metamask provides additional security by requiring a password consisting of many words that are hard to guess, thereby protecting your cryptocurrency from theft and unwanted access [110].

E. HYPERLEDGER FABRIC

This tool offers many features and capabilities that can be leveraged to produce efficient and versatile applications. This method ensures that all information and amenities exchanged are confidential, accurate, and secure. The Linux foundation's membership services and consensus are made possible through a comprehensive and collaborative digital platform. The chain code digital contract mechanism underpins this open-source platform, making its permission-based design available to anybody. The platform's compatibility with Go language, Just Another Virtual Accelerator (JAVA), and JavaScript Object Notation (JSON) increase its flexibility and applicability across various sectors, from finance and healthcare to government and manufacturing. There are many benefits to using this platform, but there are also some negatives to think about. Aside from a few rudimentary software development kits, the platform's lack of strong interface support is a major drawback. This may restrict what may be built on the platform and the options available to developers. Additionally, network performance reliability may fall short of expectations due to insufficient fault tolerance and inexperienced programmers [111].

F. HYPERLEDGER IROHA

Hyperledger iroha is an advanced and versatile framework that facilitates the creation of globally accessible databases for use in various endeavours. With its crash-resistant consensus mechanism in place, your data is safe and secure.

The framework's versatile programming language also makes it a great option for customer software development because it can be adapted to fit specific needs in each application's domain. Because of its adaptability and versatility, it creates innovative, high-quality software applications. As a result of its many benefits, it has found application in SCM systems, where it has facilitated adaptable object discovery within a decentralized supply-chain framework with semantic enhancements [112].

G. HYPERLEDGER SAWTOOTH

The hyperledger sawtooth's design is so flexible and responsive that it can easily incorporate new modules. This entails that the fundamental system is completely separate from the domain of apps, allowing business rules to be defined using smart contracts without a deep understanding of hyper ledger sawtooth's architecture. Moreover, hyperledger sawtooth provides a wide selection of consensus methods, such as PoET and pBFT. These enhancements guarantee the platform's flexibility and capacity to meet the needs of a wide range of businesses. As per reference [113]. Utilizing this technology in aerospace systems enables infinite nodes to connect and function seamlessly in the blockchain network, thus significantly improving its scalability. Moreover, it boasts exceptional proficiency in power consumption, parallel scheduling, translation management, and the ability to handle byzantine failures easily.

H. HYPERLEDGER CALIPER

The hyperledger caliper is a powerful and practical instrument for measuring the efficacy of blockchain implementations. This tool provides pre-established scenarios to analyze the efficacy of blockchain implementation. Several blockchain solutions work with this tool. Users can gain a deep understanding of how their blockchain implementation functions with the help of the reports generated by hyperledger caliper, which cover a wide range of performance parameters. The efficiency and effectiveness of the blockchain deployment can be greatly enhanced with the information provided by these reports. Both the healthcare industry and the intellectual property system have effectively implemented hyperledger caliper technologies [114].

I. MULTICHAIN

Multichain is an internal blockchain network developed specifically for businesses. It is a fork of bitcoin's original code that may be used to build and implement secure blockchain networks within businesses. In multichain, the amount of nodes in the internal blockchain is unlimited [115]. Various APIs are used to access nodes and their associated operations. Multichain nodes require the approval of the primary node before they can generate resources, streams, or mine. In a multichain system, just the node that produced the resource can move it to different nodes in the wider network. A multichain asset could represent anything from money to papers to physical items. Outside of the multichain ecosystem, the value of multichain resources may be negligible.

J. HYPERLEDGER INDY

Decentralized identities can be developed and kept on the hyperledger indy distributed ledger, giving users full authority over their online identities. Instead of storing personal information, it keeps track of references to identities. Worldwide identities that are not issued or managed by a centralized organization are called Decentralized Identifiers (DIDs). The confidential key is kept secret by the owner and is used to decrypt the public key. Indy uses agents and wallets for DID management [116].

K. R3 CORDA

Corda is a decentralized ledger that uses smart contracts to secure user data. It improves processes, saves money, and accelerates the processing of transactions. Corda's key features include excellent efficiency and scalability, confidentiality, international data exchange, authorized access only, identity verification, and absolutely no mining or digital currency. In corda, every single node maintains its database, which keeps track of that node's transactions [117]. This indicates that there is no main accounting system. Every node in a corda network operates as a peer, running an instance of corda itself. All internal communications between nodes are encrypted and point-to-point. The core four corda network assistance among the nodes are as follows: The identity assistance is responsible for authenticating and authorizing network nodes. Validating a participant's document signing request aids in inviting them to join the network. Network assistance: This service aids in the process of creating a network map, which in turn aids in the routing of messages and the interconnection of various nodes. The notary's services aid consensus on originality. Service assistance: This aids in answering questions concerning the three hubs as mentioned earlier [118].

V. CHALLENGES EXIST WITHIN TRADITIONAL SCM

Blockchain technology is often discussed as a solution to common issues in SCM. The reason for transitioning to a blockchain-based solution is to provide a secure, reliable, decentralized, distributed ledger that cannot be altered. By recording transactions sequentially, blockchain ensures that they cannot be changed. Utilizing blockchain technology has demonstrated its effectiveness in addressing numerous challenges and problems. Its exceptional attributes enable swift and safe handling and distribution of data and foster confidence and openness across different domains and fields.

A. ACADEMIC SYSTEM

Concerns confronting the academic sector are as follows. The current state of academia and the education system is fraught with various challenges and ongoing investigations. These issues are diverse and complex, requiring a multifaceted

approach to address them adequately. One of the primary impediments we encounter in education today students are not engaging with the subject matter with digital content. This disinterest and lack of effort can negatively impact their academic progress. Fortunately, blockchain technology could be a viable solution to address this issue. By offering a valuable incentive system that rewards students for their accomplishments, it is possible to improve the education system for everyone involved - students, teachers, and parents alike [119]. Another academic issue is that parents must easily access their child's academic details and results to make informed assessments. The implementation of blockchain technology is essential to ensure transparency and accountability in school spending. With the help of this technology, parents may keep track of their child's learning trajectory in real time instant and take an active role in their education. By providing parents with this level of transparency, and schools can foster a more collaborative and trust-based relationship with families, ultimately leading to better student educational outcomes [120], [121].

B. AGRICULTURE AND FOOD SUPPLY CHAIN

The agricultural industry faces several challenges, such as inadequate measures for food safety, the inability to track food sources effectively, accommodating dynamic consumer preferences, and the high cost of transactions. The amplified use of pesticides and fertilizers has intensified concerns about food safety. Ensuring agri-food product safety is paramount in the food industry [122], [123]. The recent surge in consumer and governmental concerns over the safety of food products has spurred renewed efforts to implement effective monitoring measures throughout the supply chain. Traceability within the food supply chain plays a vital role in achieving this objective by providing a comprehensive understanding of the origin and journey of food products. A better understanding of the manufacturing process results in greater quality assurance and safety procedures, inspiring trust in the calibre and reliability of food items among customers and business participants [124], [125].

Implementing such measures is instrumental in creating a healthier and more sustainable food system, which is the ultimate goal of the food industry. Therefore, it is essential to meticulously monitor the food supply chain to ensure that the safety of agricultural products is given the highest priority. According to the source [126], blockchain presents a workable solution for managing food production, supply, and transactions, effectively addressing the mentioned challenges. In the past, agricultural supply chain information was typically stored in centralized data repositories, but these systems were often unable to accommodate complex data. However, with the advent of modern technology, a new type of distributed ledger has emerged. This technology has been specifically designed to store data about the food supply chain in separate locations, simplifying computing processes and offering a range of other benefits, such as increased scalability, transparency, trust, and lower energy consumption in data management. Blockchain is a highly effective solution for managing complex agricultural supply chains more efficiently and securely [124].

C. BANKING SYSTEM

Concerns confronting banking are as follows, it is of utmost importance that financial institutions uphold their duty to safeguard their client's confidential information and promote accountability. In blockchain, various easily accessible tools are utilized to ensure the secure storage of data and efficient handling of transaction records. These tools employ a consensus algorithm that allows for the effortless addition of new transactions to blocks, which can then be linked together to create a chain. This method ensures the highest level of security and reliability in handling sensitive financial data. The financial industry places great importance on safeguarding the personal data of its customers [127], [128]. In light of various security threats such as information leaks, data breaches, and unauthorized monitoring, it is imperative to take measures to mitigate such risks.

One effective solution is implementing a blockchain-based distributed ledger system, which ensures secure data storage in an immutable and tamper-proof manner. This system utilizes a secure time-stamp, public consensus, and audit, providing an added layer of security to prevent data theft and unauthorized access control violations [129]. The undeniable potential of blockchain technology lies in its ability to significantly reduce transaction costs by eliminating intermediaries from the process. This is made possible through the implementation of smart contracts, which enable self-execution and data storage on the blockchain. Banks can leverage the system's distributed nature and immutability to instil confidence among all participants, making it the ideal solution for those seeking highly automated features. Banks that have adopted blockchain technology have already reaped the rewards of its rigid and efficient approach, experiencing substantial savings [130].

D. HEALTH CARE SYSTEM

Concerns confronting health care are as follows. Hospitals have a crucial responsibility to ensure that patient information remains confidential and secure at all times. However, there may be instances where patients need to share their health records with third-party entities, such as pharmacists, to receive the appropriate medication [131]. This can understandably cause a great deal of uncertainty and anxiety among patients. Establishing a robust system that safeguards their personal data is more critical than ever. One potential solution to address this concern is leveraging blockchain technology. Creating a unique identifier known as a hash for each patient's medical records allows access to patient disease data without revealing personally identifiable information. This approach not only helps to protect patient privacy but also enables them to maintain control over who can

access their sensitive information. Patients can choose which third-party entities are authorized to view their medical records and can revoke access at any time [132], [133]. These measures are critical in ensuring that medical records are managed securely and that patient privacy remains always protected. Utilizing blockchain technology allows hospitals and other healthcare providers to establish a more robust system that prioritizes the protection of confidential data and empowers patients to manage their healthcare information. Clinical trial data privacy and security are paramount to researchers [134]. Maintaining the confidentiality of such data is crucial to ensure the integrity of the clinical trial process and prevent tampering, breaches, or theft.

Fortunately, the emergence of blockchain systems is an effective remedy for the above-said problem. Using the SHA, blockchain creates cryptographic hashes of the data and links them together in a chain of immutable blocks. This technique ensures the authenticity and accuracy of the data and makes it nearly impossible for anyone to tamper with it. Sharing clinical trial data across different protocols, websites, and systems can be done more securely with blockchain technology. This provides an excellent solution for privacy protection and allows for permission-based access [135]. This guarantees that only authorized parties, such as regulatory bodies and funders, can access the data and monitor its progress. By utilizing blockchain technology, individuals can effortlessly keep track of their health data progress while guaranteeing secure and easy medical records management. This level of control empowers users to trust the accuracy and management of their valuable health information.

Blockchain technology has proven to be a game-changer in protecting the confidentiality, availability, and integrity of information gathered during clinical trials. This innovative technology utilizes a secure hashing technique and a permission-based management system that can benefit researchers, regulators, funders, and patients alike. By utilizing blockchain technology, clinical research can be conducted with enhanced trust and transparency, leading to a more efficient and effective process. Furthermore, this form of technology can assist in lowering the possibility of deception and mistakes, improve the precision of information, and encourage more transparent procedures in clinical research. Overall, blockchain technology is positioned to revolutionize the landscape of clinical research, ushering in a new era of innovation and efficiency.

On the other hand, counterfeit pharmaceuticals are a grave concern in the healthcare industry, both in terms of production and distribution. These counterfeit drugs are often labeled as authentic products, deceiving consumers into believing they are purchasing a reliable medication [136]. However, the consequences of using these fake medications can be dire. They may lack the necessary active ingredient, contain the wrong ingredient, be of poor quality, have impurities, or be expired and repackaged. Furthermore, the manufacturing facilities for these counterfeit drugs are often inadequate, and the formulations are frequently incorrect [137]. Many countries are now mandating or strongly recommending implementing drug Tracking and Tracing (TT) systems to address this issue. These systems allow for the effective tracking of the movement of drugs from the manufacturer to the consumer. As a result, all medications can be verified as genuine and safe for consumption. This is a crucial step in ensuring that patients receive the appropriate medication and are protected from the potentially harmful effects of counterfeit drugs [138], [139]. Within the pharmaceutical industry, implementing blockchain technology is of utmost importance in maintaining the integrity, verifiability, and accessibility of drug provenance records. Given the industry's critical nature, blockchain technology provides a secure and transparent system that helps prevent fraudulent activity while ensuring that accurate information is readily available to all relevant parties. With its ability to securely trace pharmaceutical products throughout the supply chain, blockchain technology is an essential tool that cannot be overlooked.

E. E-VOTING SYSTEM

Voting has traditionally involved a rigorous process in which voters must register with the election commission before casting their ballot. Two primary methods are available on election day: in-person voting or mail-in voting [140]. However, it is crucial to note that the latter option requires the ballot to be received by the authorities before the deadline. While in-person voting may seem like a more straightforward process, it is a fairly costly one. This is due to the extensive measures that must be taken to verify the voter's identity, manage and staff polling stations, and ensure the secure storage of ballots to guarantee the accuracy of the results [141]. The voting process was plagued by many issues, such as delays, inaccuracies, and unreliability, which ultimately gave rise to a lack of precision and efficiency. This, in turn, led to a widespread erosion of trust in the system as people began to lose faith in the voting process's ability to reflect their preferences accurately. It's no surprise that blockchain-based electronic voting solutions are attracting interest from governments throughout the world. Many companies have responded to the market need by creating their versions of these systems. In contrast, many universities have investigated them to make the voting process more transparent and secure [31], [142].

F. LAND REGISTRY SYSTEM

Concerns confronting land registration are as follows. The land registry is a crucial resource that is vital in providing comprehensive and detailed information about specific properties. This database contains extensive, detailed, in-depth information about a property's legal proprietor, geographical location, and related assets [143]. These records are carefully overseen and meticulously maintained by authorized institutions to ensure they are accurate, up-to-date, and dependable. Examining a property's legal documents can gain invaluable insight into its past, including details about

previous owners, sale dates, and a comprehensive legal description. This information benefits those wishing to delve deeper into a property's history and understand its past. Whether you are a curious homeowner, a dedicated real estate professional, or simply someone interested in the rich history of a particular property, consulting the land Registry records can be highly advantageous. With its wealth of detailed and comprehensive information, the land registry is an essential resource for anyone looking to understand the properties in their area better [144]. Within the Indian government, specific departments are tasked with various responsibilities related to land registration. The revenue department collects land taxes and maintains the document of entitlements, which refers to registering all land parcels within a given area. This essential document provides information on the land's ownership, area, and type of soil present. It also records information on crop yields, irrigation facilities, and any outstanding liabilities. On the other hand, the survey department updates and manages city town maps and spatial land data. This department's primary objective is to ensure the accuracy of all maps and the land data contained within them. This information is essential for property owners, prospective buyers, and developers, providing a clear picture of the land's location, boundaries, and other significant features [145].

The registrar's role is equally important, as they are responsible for registering and monitoring all deeds and other property documents. This includes assessing and collecting stamp fees, which are a vital source of revenue for the government. The registrar's office plays a significant role in ensuring that all property transactions are legitimate and transparent. However, despite the government's efforts to maintain an efficient land registration system, several issues arise. One of the most significant challenges is determining the valid owner of a property, particularly in cases where the land has been passed down through generations without proper documentation. Disagreements over who should be the official owner of a property can also cause disputes. Disputed land cannot be bought or sold, and these disputes account for 66 % of all pending court cases in India, with an estimated delay of 20 years from the time of the undertaking. Such delays can harm the economy and significantly impact property owners and developers [144]. Fortunately, the advent of blockchain technology presents a promising solution to these problems. With its immutable and transparent nature, an impenetrable history of land ownership can be produced using blockchain technology, reducing conflicts and making it simpler to determine who is the true owner. Moreover, blockchain technology can automate the entire land registration process, significantly reducing the time it takes to complete a transaction [146].

G. GOODS AND SERVICE TAX (GST)

When it comes to conducting business within a country, the GST is a crucial element to consider. The vendor collects this tax at the point of sale and then remits it to the government. It is important to note that a consistent GST rate is typically enforced throughout the entirety of the country, ensuring fairness and equality in tax collection. Despite this, certain complexities and challenges may arise when implementing and managing an effective GST system, requiring careful attention and consideration from all parties involved. Implementing the GST has been challenging for many countries, and India is no exception [147]. The GST system has posed several difficulties that affect businesses of all sizes, including high compliance costs, a complicated tax system, and the e-way bill system, increasing the burden on businesses. However, there is hope that blockchain technology can provide a practical solution to these issues. By employing the power of a distributed ledger, blockchain can simplify firms' compliance requirements and aid in tax revenue collection. Blockchain technology can provide high transparency and security, enhancing the GST system's trust and compliance and ensuring the system is free of fraudulent activities [148].

The taxation system hopes to gain many advantages from blockchain technology. Blockchain technology can streamline the GST system, reducing the compliance burden on businesses. For example, blockchain technology can automate the process of generating invoices, making it easier for businesses to comply with the GST system. Additionally, blockchain technology can provide real-time tracking of goods, which can help prevent tax evasion and improve tax revenue collection. Blockchain technology can pave the way for a more efficient and effective tax system that businesses can easily comply with, reducing the burden on businesses and improving tax revenue collection [149].

H. AUTOMOTIVE INDUSTRY

Concerns confronting the automotive supply chain are as follows: The automotive industry's supply chain is a highly intricate network of forward and reverse manufacturing processes involving many parties. These parties include the auto parts manufacturer, the vehicle maker, the dealer, and, ultimately, the end consumer. Each entity is pivotal in ensuring high-quality vehicles are produced and delivered promptly and efficiently. Their collective efforts strive to provide the end-user with the best possible experience when buying and owning a vehicle [150], [151]. According to a study conducted by [152], it has been observed that several systems within automobiles have the potential to malfunction, including electronics, steering, and gasoline. Surprisingly, the study has found that nearly half of all recalls involve critical auto parts and systems. Such recalls can have a severely detrimental impact on a company's reputation and financial performance. As such, car manufacturers must ensure that their vehicles are thoroughly tested and maintained to avoid such issues. Recalls in the automotive industry can be caused by various factors, from design flaws to using counterfeit parts [153]. Other factors contributing to the need for recall include subpar production quality and

incorrect labeling. It's important to note that even minor errors can have significant consequences and lead to a recall. The information provided is supported by reputable sources such as. Automobile recalls are a crucial matter that should be addressed with utmost care and responsibility. Automakers must proactively engage with all relevant stakeholders and consumers to deal with this issue effectively. This involves providing comprehensive and up-to-date information and data to ensure everyone is well-informed and equipped to make informed decisions. By doing so, the safety and well-being of all parties involved are prioritized and protected.

Effective SCM requires high collaboration and trust between all parties involved, especially in product recall. Maintaining open communication channels and sharing relevant information is imperative to address any issues that may arise and to prevent similar incidents from happening in the future. Transparency plays a crucial role in this process, as it involves being honest about what we know and don't know, which helps build and maintain trust among all stakeholders. By fostering transparency and cultivating trust, creating a safer and more efficient supply chain is possible. By leveraging the power of blockchain technology, automotive supply chains can establish a robust and trustworthy system for managing product recalls [154]. This cutting-edge solution ensures transparency and accountability throughout the recall process, providing stakeholders with a reliable and secure mechanism to track and manage product defects. With blockchain, manufacturers, suppliers, and other stakeholders can collaborate seamlessly to identify and address issues, ultimately enhancing customer safety and satisfaction. By establishing a secure mechanism for tracking and managing product defects, stakeholders are empowered to work collaboratively towards identifying and addressing issues. Ultimately, this approach leads to enhanced customer satisfaction and safety [155].

VI. IMPLEMENTATION OF BLOCKCHAIN TECHNOLOGY IN SCM

A. PHARMA SUPPLY CHAIN PROCESS

The illustration showcases a meticulously crafted framework by the authors of [41] in their work for the medication traceability system. It provides a clear overview of all the stakeholders involved and the various interactions that take place with the intelligent contract. This architecture has been thoughtfully designed to ensure that the medication traceability system operates smoothly and efficiently, with all stakeholders having a clearly defined role in the process. The participants will communicate with the intelligent contract to launch pre-authorized procedure calls and with the P2P storage platforms to gain authorization for data files. In addition, their interactions with the on-chain assets are intended data like records, hashes, and events. With the use of advanced software-enabled devices that come with a DApp front-end layer, an intelligent contract, and an API, all parties involved can have complete control over the intelligent contract, self-governed storage system, and on-chain assets. This inclusive approach ensures absolute clarity, safety, and responsibility across the entire transaction process, enabling a seamless and trustworthy value exchange.

The authors utilized the ethereum blockchain as the primary framework for establishing a robust and efficient system architecture. The chain code, which governs the system's core functionalities, is developed using the solidity programming language and executed on the REMIX Integrated Development Environment (IDE), a powerful online platform designed to support solidity scripts. This combination of cutting-edge technologies ensures that the system operates at optimal performance levels while maintaining high security and reliability. As depicted in figure 12, the method employed by the drug producer in manufacturing medicines is primarily propelled by market demand. The regulatory approval process, which the Food and Drug Administration Authority (FDA) oversees, is crucial in facilitating the utilization of smart contracts by the manufacturer. After obtaining the necessary regulatory approval, the manufacturer establishes a smart contract that comprehensively outlines all the relevant information regarding the medications produced.

Furthermore, the supply chain participants are promptly notified to ensure a seamless and efficient distribution process of the drugs. New participants can access the comprehensive list of all transactions saved in the IPFS as part of the network. This makes the entire supply chain open and responsible to everyone. The manufacturer is responsible for informing all parties involved in the process once they have obtained all necessary permissions and have the medications ready for distribution. Interested buyers can access the required smart contract functions to purchase the drug. Once a successful purchase is made, an event is announced to indicate the new owner of the medication. The smart contract deployed to facilitate the sale of the medication utilizes a variety of attributes and functions such as bundle-Name, bundlecost, boxcost, image, and bundle details. These inputs include bundleName, bundlecost, numBoxes, boxcost, IPFS hash, owner ID, customer, vendor, and caller. The owner ID serves as a unique ethereum address that identifies the new owner of the medication.

When creating a bundle contract, the manufacturer needs to provide several details. Firstly, the bundle name should be a string that can be used to identify the bundle. Secondly, the number of boxes included in the bundle must be specified as a whole number. This information is crucial in determining the total cost of the bundle. Additionally, the manufacturer must provide the total Number of Boxes ordered by the Customer (NBRC), represented by the NBRC value. It's important to note the cost of each box in the bundle, which is represented by the boxcost value. This information helps calculate the total cost of the bundle, which is indicated by the bundlecost value. To ensure the bundle's security, the image must be hashed with a 256-bit key (or 32-byte), and the resulting hash should be included in the contract as the IPFS hash value.

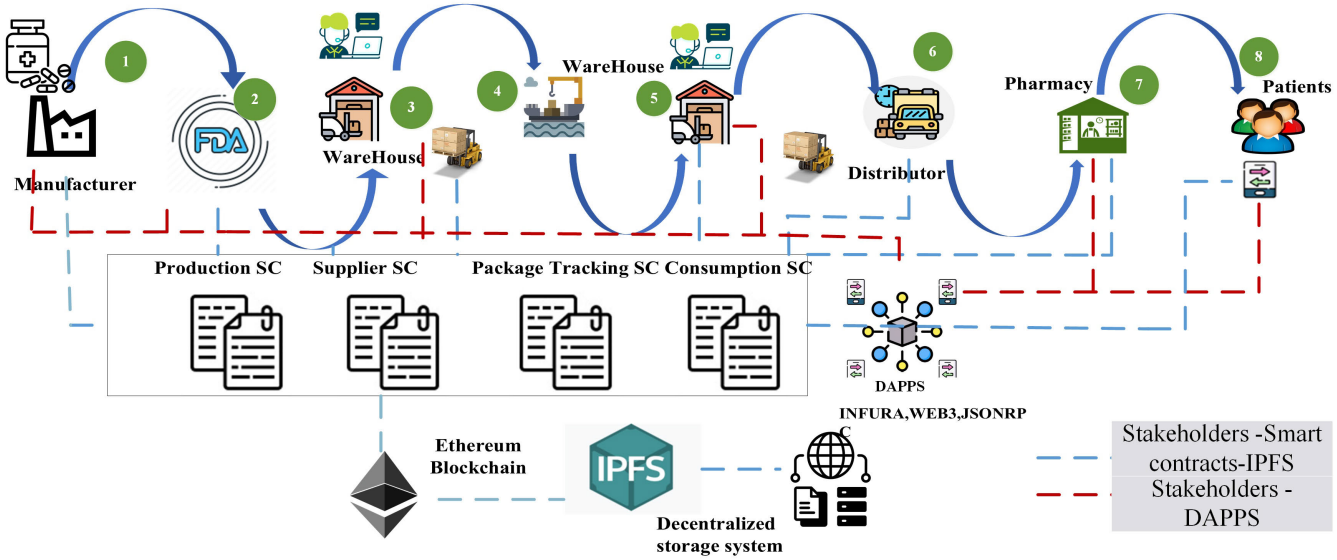

FIGURE 12. The use of blockchain technology in the pharmaceutical supply chain process.

Other necessary details that should be included in the bundle contract are the ethereum addresses of the owner, customer, and supplier within the supply chain. The ownership of the bundle is established through the use of the ethereum address, with the customer and supplier being identified through their respective ethereum addresses. Lastly, mapping the customer's address to the purchased boxes must be provided. It is important to note that an error message will be returned if the caller is not the owner ID. Once the bundle is created, a confirmation string will be returned to indicate that the bundle has been successfully created and the server has received the bundle image. To purchase the bundle, the seller and buyer must agree to the terms. The bundle cost should be transferred to the vendor via a transaction with an equal amount. The sale of the bundle should be declared through an event, which requires using an enum to replace the vendor's address with the customer's ethereum address and modify the ownership ID accordingly. To successfully purchase bundle boxes, specific criteria must be fulfilled, regardless of whether the client or vendor makes the request. The bundle box cost must be transferred to the vendor to calculate the transaction amount, which can be determined by multiplying NBRC with the box cost. Following this, the ownership ID should be altered by replacing the vendor's ethereum address with that of the customer, which will also update the number of boxes owned by the vendor.

The authors meticulously crafted the smart contract in their work to integrate a one-of-a-kind owner identification system, effectively facilitating the smooth and hassle-free management of the medicine's ownership. To establish transparency and accountability, the contract will also showcase an event-triggered architecture that will promptly and securely record all alterations in ownership into a tamper-proof ledger. This cutting-edge feature will act as a dependable tracking mechanism, providing all stakeholders with a comprehensive and succinct overview of every transaction and change made to the medicine's ownership history, ensuring complete clarity and accuracy at all times. This study proposes that the decentralized P2P ethereum blockchain may serve as a preventative measure against fraudulent activities. The study uses the blockchain's tamper-proof records, events, and immutable data transfer property to highlight the supply chain process. The study, which is marketed as effective, also focuses on cost comparisons based on effectiveness. Future advancements in the pharmaceutical supply chain are being investigated to improve the planned work.

B. BLOOD DONATION SUPPLY CHAIN PROCESS

The authors of [39] have proposed utilising blockchain technology in blood donation management systems, as illustrated in figure 13. Their approach was evaluated through a thorough analysis of efficiency and security. Their suggested system encompasses various aspects of blood donation systems, including blood unit collection, delivery, request, and transfer. The current blood donation management systems in use often lack vital features such as traceability, immutability, transparency, confidentiality, audit, and safety. This article presents a technique for handling blood donations using a safe and private ethereum blockchain. The entity-relationship diagram, sequence diagrams, management strategies, and structure are all clearly explained in this article. A thorough security analysis is also used to discuss the approach's effectiveness and utility. The overall framework of the suggested solution, which comprises two smart contracts for consumption and production, is shown in Figure 13. Authorized parties can utilize these smart contracts via DApps and APIs. Smart contract functionality can be accessed through various APIs, such as Infura, JSON Remote

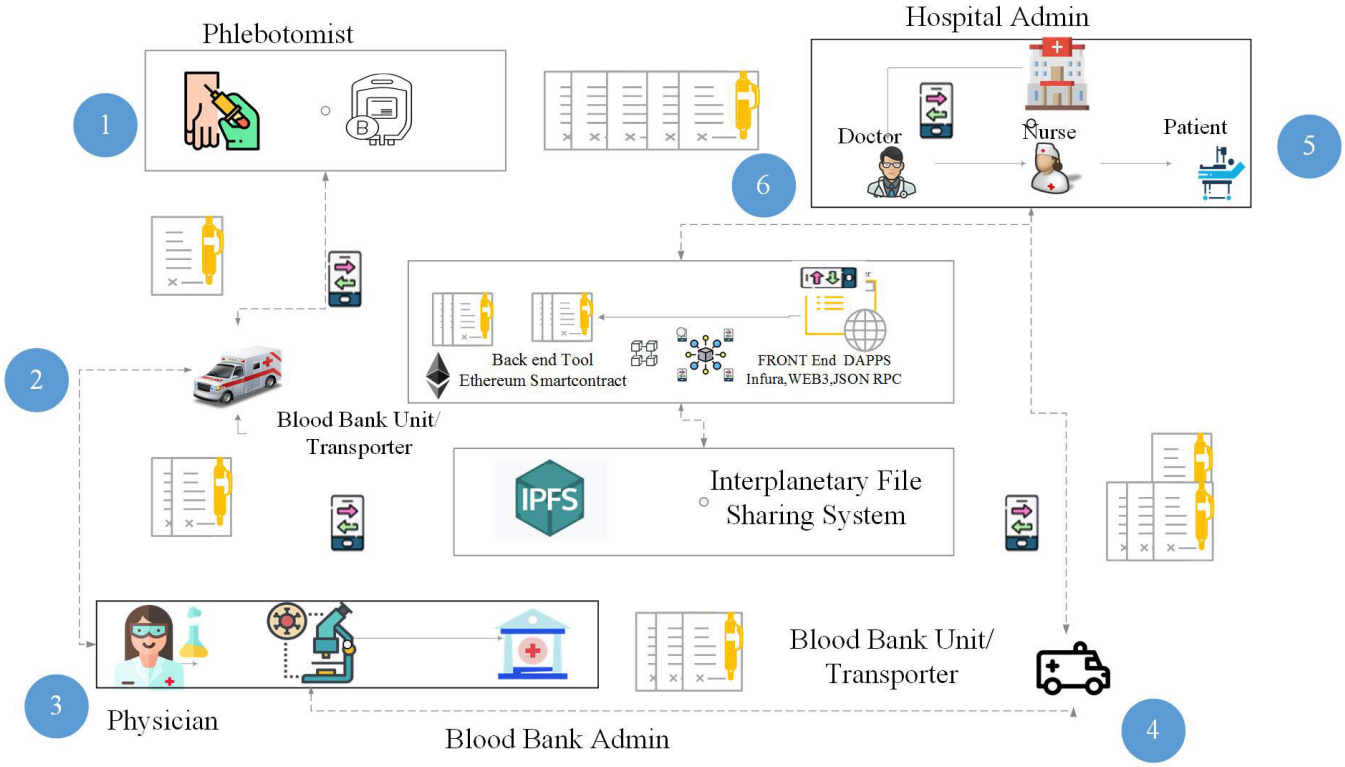

FIGURE 13. The process of blood donation supply chain using blockchain.

Procedure Call (RPC), and the help of Web3. A smart contract is a complex system comprising various variables, including an ethereum address accessible only to the blood bank technician and phlebotomist. This address ensures that only authorized individuals can access the system and transport the blood units from the donor sites to the blood banks. The transporter mapping system is a built-in feature that ensures that only authorized personnel can transport the blood units. This system is designed to prevent unauthorized access and ensure that the blood units are transported safely and efficiently.

The ''Blood Unit Status'' (BUS) variable is a critical smart contract component. This variable tracks the various stages of the collected blood unit, such as ''Not Ready'' (NR), ''Ready for Delivery'' (RD), ''Start Delivery'' (SD), ''End Delivery'' (ED), and ''Blood Unit Received'' (BUR). The ''BUS'' variable is essential in ensuring that the blood units are tracked efficiently and delivered to the right recipients. The enumeration variable Blood Component Type (BCT) is another critical smart contract component. The necessary variable is provided in the format of an unsigned 8-bit integer, where ''0'' represents '' Red Blood Cells'' (RBC), ''1'' represents ''plasma'' and ''2'' represents ''platelets.'' This variable is essential in ensuring the right blood type is delivered to the right recipients. Ensuring that the blood units are handled appropriately during transportation is also crucial.

Overall, the smart contract is a highly sophisticated system designed to ensure that the blood units are transported safely and efficiently. The various components of the contract work together seamlessly to ensure that the blood units are tracked and delivered to the right recipients. Phlebotomists utilize smart contracts to keep track of received blood units. The contract includes their ethereum addresses, donor IDs, and the ethereum addresses of blood bank technicians. Once activated, the blood unit tracking process starts. Trustworthy transporters will be given future authorization-related tasks. There are five fundamental stages to the blood unit monitoring procedure. Initially, the phlebotomist draws the entire blood unit and signals that it's RD. The designated transporter shall retrieve the unit from the phlebotomist to initiate the delivery process. Once the complete unit is received, the blood bank technician announces it and declares the BCT, quantity, and expiration date. The consumption smart contract includes variables of various types, and the administration of hospitals and blood banks is included in the ethereum address. Mapping of transporters, physicians, and nurses is completed in the smart contract consumption. Only transporters whom the blood bank has authorized are permitted to deliver orders for blood units to the hospital. The blood bank administration owns the consumption smart contract in this instance, which also includes information on the starting time for deployment, the hospital administration's ethereum address, and the initial state of the blood component

unit. The consumption tracking process starts when the smart contract is launched, and the blood bank management assigns reliable transporters while the hospital administration assigns reliable doctors and nurses.

The consumption process for blood components involves six key steps that ensure the safety and efficiency of the process. Firstly, a doctor must authorize the request for a unit of blood component, which should include details such as the blood type, the amount needed, and the date of the request. Requests can be made for RBC, plasma, or platelet units. Once the blood bank administration approves the request, a designated transporter will collect the blood component unit and initiate the delivery process. Upon receipt of the order by the hospital, the delivery process is deemed to be concluded. The designated physician will then prescribe the blood unit, including the patient's ID, the type of blood component unit, and the quantity needed. Finally, the authorized nurse will declare that the consummation operation is complete after transfusing the blood component units. These steps ensure the blood components are safely and efficiently delivered to needy people. The blood donation management system proposed by the authors has undergone a thorough analysis to ensure its robustness against potential security threats and attacks. A comparison was also conducted to evaluate its effectiveness against other existing strategies. The development and testing of the DApp will be conducted on the ethereum network.

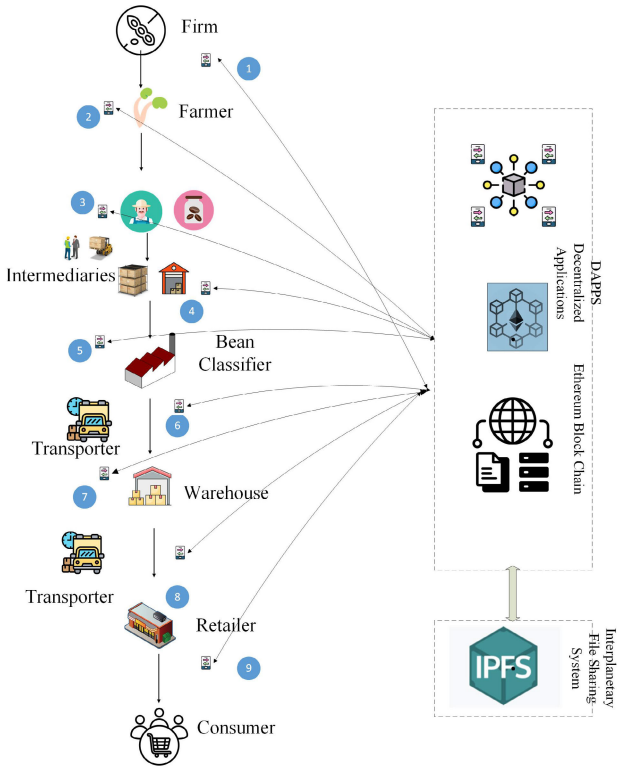

FIGURE 14. Utilizing blockchain for the agricultural supply chain process.

C. AGRICULTURAL SUPPLY CHAIN PROCESS

Managing system architecture in the soybean supply chain is complex, but an article [156] offers a helpful solution. This solution involves various parties, including the distribution centre, farmers, bean classifier, transporter, warehouse, retailer, consumer, and blockchain. As illustrated in figure 14, the EVM executes a smart contract on the blockchain, and each individual must have a unique ethereum address to participate. Private and public keys linked to an ethereum address are crucial for encrypting and verifying transaction data and connecting it to a specific account. The information contained in the smart contract pertains to the roles, affiliations, and interactions of every participant taking part in the bean cultivation and harvesting process. These participants include companies, bean cultivators, classifiers, transporters, warehouse workers, retailers, and customers. The seed companies use smart contracts to sell their products to farmers. With the help of the smart contract, the farmer's enrollment process is initiated only after the cash deposit is received. If the transaction is successful, the contract moves to the ''initiatedseedreq'' state. Subsequently, the seed company is approved, and the farmer waits for further instructions. Once the farmer plants the seeds, they update the company on their progress and select a harvest date. The contract then updates this information as ''Crop Ready for Harvesting'' (CRFH). The next stage is to give each middleman a unique ethereum address so they may bargain over the cost of the gathered crop. The middlemen will update the smart contract with the updated information, such as the price tag, quantity, date, and time of crop purchase, once a price has been agreed upon. The firm involved in bean classification then completes the next stage of the procedure after updating the details that the intermediaries had purchased. The bean classifier's employees refine the beans and update the status to ''Refining Completed'' (RC), check the beans for Moisture (M), take out any ''Extraneous Material'' (EM), and start the labelling process. The bean classification operator analyses the beans' quality before being stored and updated in the smart contract as ''Quality Good'' (QG) or ''Quality Bad'' (QB) and rates it as 1, 2. In the next step, sellers such as merchants should be given unique ethereum addresses. Integers should be assigned for ''beanid'' and ''saleid'', and the ''Trade Request'' (TQ) should be received from the customer. If the customer makes the payment, the status should be updated to ''paid''. If not, an error message will be returned. Finally, the store should update the contract status to ''sold'' with the amount, date, and time.

The authors proposed a detailed approach and framework for monitoring the traceability of soybean supply chains. The methodology involves leveraging the advanced capabilities of ethereum's blockchain technology and implementing smart contracts to track and manage business transactions with precision and efficiency. Their innovative solution aims to establish a highly effective and trustworthy system for ensuring the transparency and safety of soybean supply chains.

By doing so, they seek to benefit all stakeholders involved in the process. The network's ability to keep up its rapidity and safety while handling large transactions is notably hampered by its ability to expand the blockchain system. Another crucial challenge is governance, as the decentralized nature of blockchain makes it difficult to establish a clear authority or decision-making process. Additionally, identity registration and privacy are important concerns that need to be addressed to ensure the integrity of the blockchain network. Standards and laws governing the use of blockchain technology are also evolving, and it is essential to comply with these regulations to avoid legal issues. To overcome these challenges, the authors plan to undertake a future project to investigate these issues and develop viable solutions. They also aim to integrate automated payment and delivery verification into their proposed blockchain system, enhancing its security.

D. INVENTORY SUPPLY CHAIN PROCESS

An esteemed group of researchers [40] has recently revealed a spectacular approach that utilizes the capabilities of smart contracts on the ethereum network to take inventory sharing to new heights. This innovative method is wholly dedicated to enhancing supply chain transactions' dependability, reliability, and transparency by leveraging decentralized data storage, considered the future of data storage. To establish trust and credibility among all stakeholders, the team has meticulously developed a secure information exchange framework that integrates advanced algorithms for recording all conversations. The smart contract was crafted with the utmost care and verified using the REMIX IDE to ensure accuracy and effectiveness, leaving no room for error. The pioneering nature of this approach has garnered widespread attention and is expected to revolutionize the supply chain industry.

Suppliers play a vital role in facilitating the efficient delivery of goods to end consumers within the supply chain, as demonstrated in figure 15. To do so, suppliers must conduct thorough market research to identify what products are in demand. They must also comply with all relevant regulations and laws while determining the necessary quantity of products needed to meet customer demand. However, suppliers must also be equipped to handle unforeseen disruptions within the supply chain, such as commodity shortages or delays in raw material delivery caused by natural disasters or manufacturing backlogs due to pandemics.

On the other hand, retailers are responsible for offering various goods from various producers, distributors, and suppliers to customers. This requires retailers to effectively manage their inventory and maintain strong relationships with their suppliers to ensure that products are readily available to meet consumer demand. Retailers are the final link in the supply chain, connecting manufacturers to consumers and ensuring prompt and efficient delivery of products. To streamline processes, it has been suggested that four intelligent contracts be implemented, each with a specific function. The registration contract is intended to register all network members, while the stock level agreement provides information on the products offered by each provider and their current stock levels. The supplier reputation agreement assesses companies based on various factors, including product quality, delivery efficiency, and honesty. The order management agreement outlines how orders are received and processed. Incorporating a P2P distributed file system, such as Filecoin or IPFS, can streamline linking all network members to the same file system. With the help of blockchain transactions that maintain the time-stamped and cryptographically protected IPFS hashes, authorized network users can store vast amounts of data on IPFS. Supplier stock stacking up is explained in the following steps. The first step is establishing the initial values for the product's number, price and needed quantity. The owner's selections will be considered as the design was a unique modifier object. Suppliers will sign up for the smart contract in the following third step. Suppliers will then carry out a storage smart contract in step four after that. Suppliers may contribute product information to the storage contract in step five. Step six will involve increasing the quantity of a product and incrementing the product count after the request function is implemented utilizing the product number as a parameter. We will include a new item in the stock and set its price in step seven. Then, confidently update the price by confirming the product pricing with the necessary function in step eight.

The subsequent steps are purchase by retailers. First, set up the necessary information, such as the stock address, product number, and amount needed. After that, create an object modifier that only pertains to the retailer. The third step involves the retailer submitting a purchase order through the order management smart contract. If needed, revert the transaction in step four using the demand function. Step five requires retrieving the information about the quantity of products available from the stock smart contract. If necessary, subtract the amount from the supplier stock in step six. Finally, use the events function in step seven to emit the procurement without any issues. The final step is to modify the supplier reliability scores. To begin, enter the ethereum supply address in step one. Next, ensure that the smart contract has added the supplier's ethereum address to the list of trusted suppliers. In step three, it is necessary to provide feedback to the retailer as either true or false, leading to either proceeding with or reverting the transaction. Step four demands the provider provide a genuine service to increase their reputation. Finally, in step five, if the provider fails to deliver genuine service, their reputation will be decreased. Extensive experimentation has conclusively shown that the proposed strategy is exceptionally effective in dealing with various scenarios and system characteristics. For supply chain operations to succeed, ensuring that all relevant parties are efficiently coordinated and integrated is imperative. The crux of achieving optimal efficiency lies in establishing a seamless data exchange between both sides, significantly improving overall efficiency and productivity.

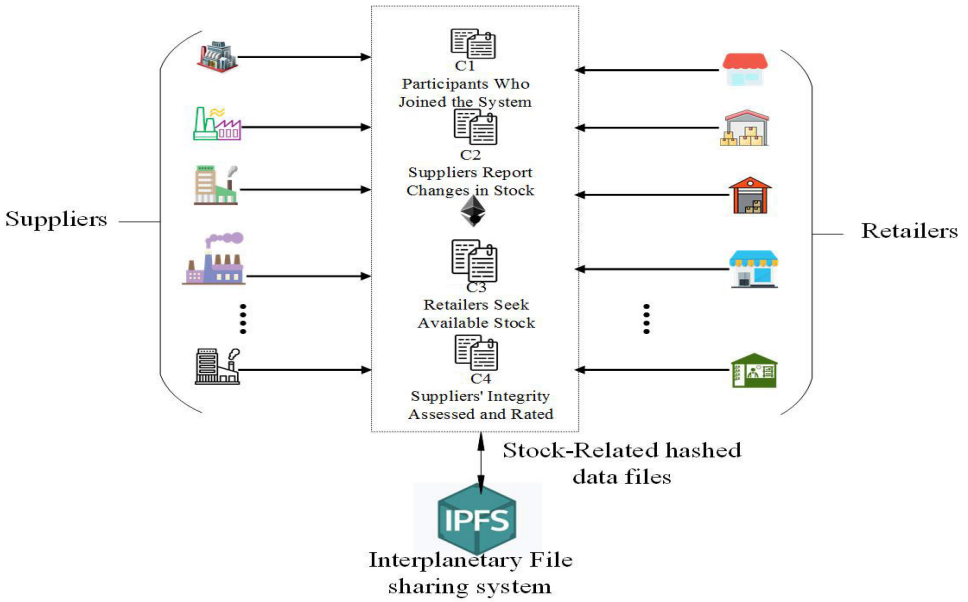

FIGURE 15. Incorporating blockchain technology into the stocking process of the supply chain.

E. FISHERY SUPPLY CHAIN PROCESS

The idea proposed in the research paper is paramount for ensuring effective SCM in the fishing industry. It is imperative to implement this idea without any delay. To develop a distributed, accessible, confidential, safe, and reliable network that intends to streamline the aquaculture supply chain, the writers suggest a blockchain-based system that uses ethereum [34]. The proposed system has five smart contracts in place to achieve this end. The fishing industry's supply chain consists of two categories - farmed and indigenous - which are distinguished based on production and harvesting methods. The term "indigenous" in the seafood industry refers to the practice of catching fish from their natural habitats, such as the ocean or a river. Establishing traceability standards is essential in ensuring food safety and preventing fraud in the seafood supply chain. However, the attainment of this objective remains a challenging task. As a result, most consumers are unaware of the species of fish they are consuming when purchasing seafood. Given these challenges, the authors proposed a blockchain-based system, which could be a viable solution to ensure greater transparency and traceability within the fishing supply chain. Advanced technology has proven to be a valuable tool across multiple industries, particularly in implementing effective product tracing systems. Regarding fish tracing, potential challenges can be addressed by integrating blockchain technology, specifically ethereum. To manage the actions involved in the fishing procurement and delivery process, the contributors of this paper recommend employing the confidential ethereum blockchain platform. This solution ensures transparency, traceability, accountability, and privacy. The authors also present a framework that describes the actors and their relationships within the supply chain. Using the EVM, users can seamlessly access these programs and execute transactions without a central authority overseeing the process. The foundation for this functionality is built upon smart contracts, which serve as the protocols that enable this process to function as intended.

As shown in figure 16, the system involves various actors and components that work together to ensure a safe and legal supply chain for fish products. The FDA plays a crucial role in registering each commercial transaction on the blockchain and ensuring compliance with the law. The fish seed company produces fish seeds or eggs through captive breeding and conducts genetic composition testing on fish to validate the species, which is stored on an IPFS database. Aquaculturists purchase fish larvae and raise them in tanks while monitoring their growth phases and environmental conditions. They also upload images and profiles of the fish as they mature for auditing purposes. Local fishermen cultivate fish exclusively in natural places and update data related to native fish before selling them to fish classifiers. The fish classifier separates different species of fish based on their origin and method of capture. The fish processor removes the skin, scales, and fins from the fish before filleting the meat. They keep the genetic testing results of the fish products on IPFS for future validation. The supplier accepts orders and ships the products to retailers who have agreed to sell them. Retailers purchase packets of classified fish from the distributor before selling them to the ultimate customer. The customer, in turn, purchases and consumes the fish product.

As mentioned earlier, the authors of the solution have developed a groundbreaking approach that can be easily incorporated into various supply chain operations. They are highly optimistic about their upcoming strategies, which include conducting extensive testing and ensuring the proper

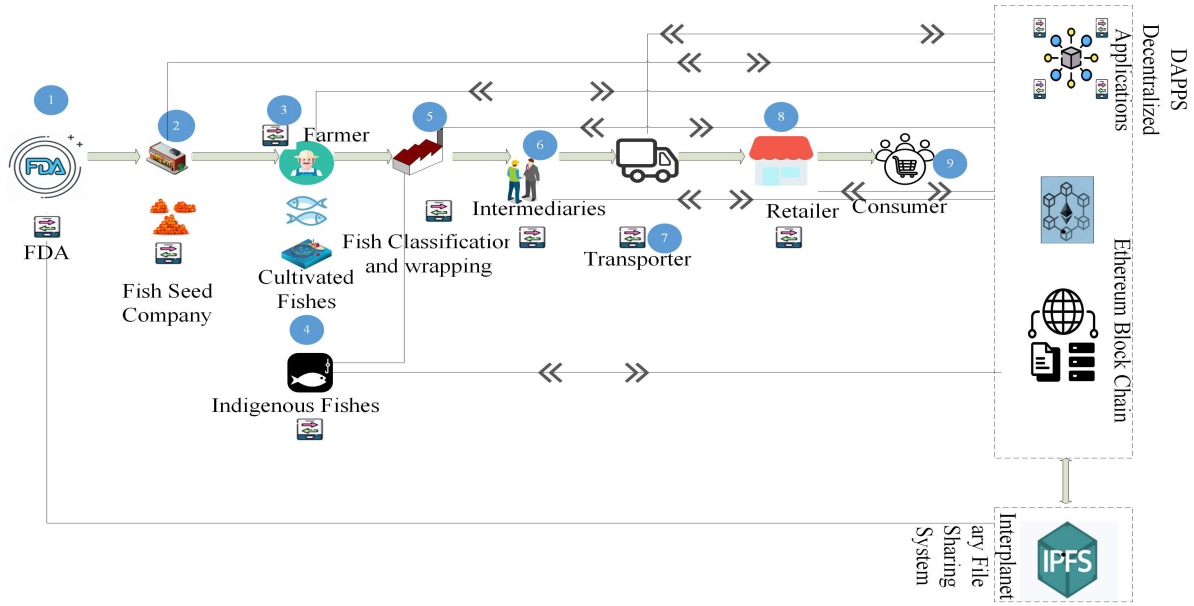

FIGURE 16. The process of supply chain in the fishery industry utilizing blockchain technology.

implementation of the solution on the ethereum network. Furthermore, their primary objective is to craft tailor-made DApps that cater to the particular demands of the diverse stakeholders engaged in such procedures.

VII. FUTURE RESEARCH DIRECTIONS

After conducting extensive research, it has been determined that certain areas within the scope of this study require attention. These findings have been derived through a meticulous examination of the subject matter and have been thoroughly analyzed to ensure accuracy. In the future, to maximize the benefits of blockchain technology, researchers must carefully consider several complex factors.

- These factors include scalability, the risk of double-spending, an unstable operating environment due to changing protocols, inefficient incentive strategies, the possibility of transaction malleability attacks, high energy consumption, and longer transaction times compared to traditional payment methods like cash or credit cards.
- Incorporating blockchain technology into existing agricultural, food supply chain and healthcare systems can provide many benefits, including improving user engagement and exchanging important information efficiently.
- To enhance productivity and streamline operations, it is imperative to integrate interactive functionalities that span over various platforms.
- To establish a cohesive and seamless workflow that promotes collaboration and more efficient utilization of resources.

VIII. CONCLUSION

The paper delves into the intricate realm of blockchain topologies, evolution, architecture and their relationship with several applications in SCM, including cryptocurrencies and smart contracts. The research examines how distribution networks are affected by counterfeit items, such as unverified goods, and how this can lead to customer dissatisfaction with product quality and the poor satisfaction of customers in terms of product excellence. It also thoroughly explores the crucial aspects of development and application frameworks, along with the latest advancements in consensus algorithms. The emergence of blockchain technology has presented a novel opportunity for SCM to conduct transactions without intermediaries or geographical limitations. By leveraging blockchain technology, individuals and organizations can conduct secure transactions with greater transparency, safety, efficiency, and cost-effectiveness. The decentralized nature of blockchain technology holds immense potential to transform various industries and establish a global framework that is fair, reliable, and secure. This framework can effectively address the challenge of illicit products in SCM. It is essential for blockchain researchers to carefully analyze future research directions that can greatly impact its development and progress.

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